MODERN
GUNS AND GUNNERY,
1910.

A PRACTICAL MANUAL
for Officers of the
HORSE, FIELD and MOUNTAIN ARTILLERY.

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Entirely re-written, with numerous additional Plates
and Illustrations.

WOOLWICH:
F. J. CATTERMOLE,
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PREFACE TO FIRST EDITION.

The Official Text Book is probably the most perfect treatise on Gunnery now existing in any language. Many officers are, however, deterred from studying it by the real or imaginary terrors of the mathematical demonstrations with which its pages bristle.

For officers whose business it is to design and to make guns, carriages and ammunition, an exact mathematical knowledge of the science of Gunnery is indispensable; but for officers who have to use the gun it is sufficient to have a clear understanding of the principles of Gunnery, in order that they may be able to apply these principles to to the best advantage in handling their guns.

Thus, it is not necessary that a Field Battery Commander should know how to calculate the strains in the buffers of his guns, but it is most desirable that he should know that his shrapnel bullets cover a wider front at a long range than at a short one, if burst at the same distance from the target, and why this is so.

This book is intended to serve two purposes: first, as an easily understood manual for those whose daily duty leaves them no time to attack and thoroughly master such a difficult science as Gunnery; and secondly, it is intended as an introduction to the study of more advanced books. Many of the facts stated in this elementary manual have to be accepted without proof, as, for instance, Barlow's Law; and it is hoped that many readers will be dissatisfied with such unsupported statements and will be at the trouble to read up the demonstration of them in more scientific books.

The general scheme of this book differs in one respect from that of previous treatises on the same subject. Hitherto the science of Gunnery has been held to include only theoretical ballistics and the theory of gun construction. But with the advent of the Q.F. gun the principles of the design of the carriage and of the ammunition have assumed an importance at least equal to those governing the design of the gun; and a sound knowledge of these principles is indispensable both to the officer who designs the equipment and to his comrade who has to use it.

ALDERSHOT, H. A. B.
1.12.04.

PREFACE TO THIRD EDITION.

Only three years have passed since the last edition of this book was issued, yet the changes which have taken taken place have rendered it necessary to re-write the book throughout. Even the theoretical portion has had to be altered; we have now more perfect ballistic tables; Siacci's Beta function enables us to solve trajectories in one arc; and some of the older theories, such as that of the persistence of the spin of a rifled projectile, have been modified by recent experience.

The section on the design of guns, carriages and ammunition has been brought up to date. The subject of gun-construction has been dealt with as fully as is possible in an elementary work. The chapter on Indirect Laying has been condensed, and several pretty but useless theoretical demonstrations have been omitted. A new chapter on guns for the attack of air-ships has been added.

Later information has enabled the description of foreign Q.F. equipments to be amplified; and several new equipments are illustrated and described.

In conclusion, I have to express my obligations to Sir George Greenhill, F.R.S.; Major Phipps of the Ordnance College; Captain Maitland Addison; Captain Craig, and other officers who have kindly assisted me in writing or revising several chapters of this book; also to many officers whose ideas I have appropriated and published as my own.

WOOLWICH,
1.3.1910.

H. A. B.

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Part I.

THEORETICAL GUNNERY.

CHAPTER I.

INTERNAL BALLISTICS.

Gunnery.

Gunnery is the science of directing a projectile so that it will strike a given target.

To master the science, it is necessary to understand the general construction of the gun and carriage and the cartridge which jointly impart the motion to the projectile, and the working of the laws which govern this motion.

The Gun.

The gun serves two purposes. First, to confine the powder-gases so as to allow them to act upon the base of the shell; and second, to give the shell the proper direction.

As the powder charge burns, it is converted into gas of greatly increased volume. This gas, in its endeavour to expand, presses upon the base of the shell and drives it up the bore. So long as it continues to exert a forward pressure upon the base of the shell, it continues to accelerate the motion of the shell, and the velocity of the latter goes on increasing until it passes out of the muzzle, and the pressure on its base ceases.

Capacity of Gun.

We should get the greatest possible effect out of a charge of powder if the gun were made long enough to contain the whole of the powder gases, so that the forward pressure on the base of the shell would cease just as the shell reached the muzzle. Such a gun would however be unwieldy, and in practice we cut the gun short and allow a good deal of the gas-pressure to go to waste out of the muzzle.

Length of Gun.

The length of a gun is expressed by the number of calibres in its total external length. A Q.F. field gun is from 27 to 35 calibres long. A calibre is the diameter of the bore measured between opposite ribs of the rifling. Generally speaking, the bore is measured from the face of the breech-block to the muzzle.

Chamber of Gun.

The bore of a gun is divided, for the purpose of internal ballistics only, into two parts, the chamber and the bore proper. The powder does not completely fill the chamber, nor is it a solid mass; if a charge of cordite were compressed into a solid block it would be found to fill only about one-third of the chamber. On ignition the powder-gases first fill the chamber, and more and more gas is generted by the burning of the charge until the pressure in the chamber overcomes the resistance of the driving band, and the shell begins to move. This, in a field gun, occurs when the pressure rises to about $1\frac{1}{2}$ tons to the square inch. Henceforward the powder-pressure acts as an accelerating force upon the shell till the latter leaves the muzzle.

Work done by the Powder.

Powder, when ignited, acts in two ways. In the first place it is converted it into a volume of gas greater than that of the powder: in the second place the heat of the explosion further increases the volume of this gas, and so its pressure. Up to the point when the shell moves, the powder-gases only expand so as to fill the chamber, and do no work on the shell; during their expansion from the volume of the chamber to the volume of the whole of the inside of the gun they expend their energy, or part of it, on increasing the velocity of the shell. Hence, to find the amount of work done by the charge of powder on the shell, we find, by comparison with a standard arrived at by experiment, the amount of energy developed in expanding to the full capacity of the gun, including the chamber, and deduct from this the energy developed in expanding to the capacity of the chamber alone.

Pressure in Bore.

Forty years ago the only explosive used in guns was coarse black powder. The whole of the charge was converted into gas almost immediately on ignition, thus developing a very heavy pressure in the powder-chamber, which rapidly fell as the shell moved up the bore. Guns of this period were therefore made of a very pronounced bottle shape, enormously thick at the breech.

As an improvement on this, pebble powder was devised. This consisted of cubical grains of from $\frac{1}{4}$ inch to $1\frac{1}{2}$ inches. These burnt more slowly, giving a less pressure at the start and a better-maintained pressure as the shell travelled up the bore. Guns were then made thinner at the breech and thicker towards the muzzle.

Prismatic powder, pressed into large six-sided prisms, was the next step; this was followed by slow-burning brown powder, known as cocoa powder.

Now we have smokeless powder, in thick cords, tubes or tapes for long guns and fine strings for short ones. This has enabled us to adjust the pressures in the bore so as to get the maximum of work out of the gun with the minimum of metal.

Curves of Pressure.

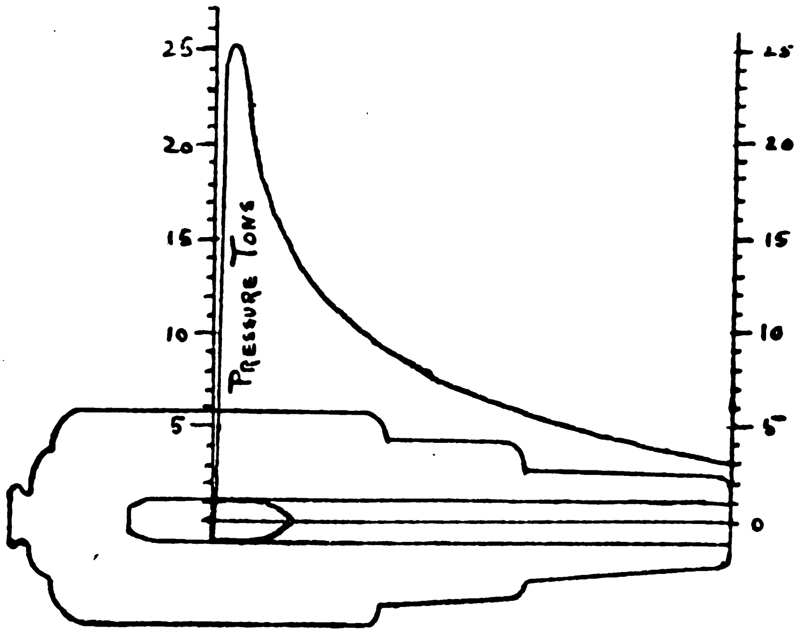


FIG. 1.

A simple and convenient means of showing graphically the pressure in any gun is by the use of pressure curves.

Fig. 1 gives the curve for the 12″ R.M.L. gun, using black powder. Here the height of the curve represents the pressure in tons at that particular point in the bore. We note how the pressure rises from 0 to 24 tons per square inch before the shell begins to move, and runs up to 25 tons before the shell has travelled half its length. The pressure then rapidly falls, till at the muzzle it is only 3 tons per square inch.

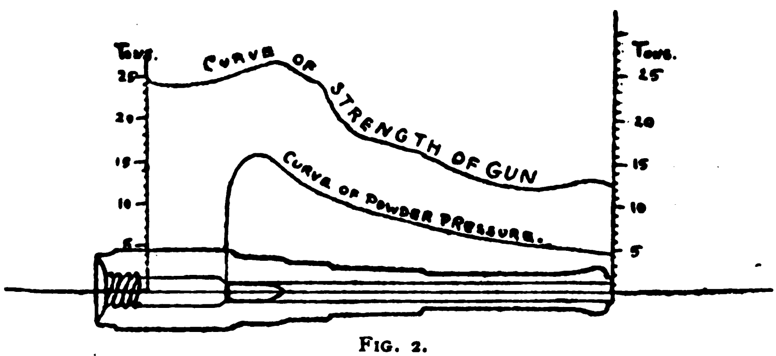


FIG. 2.

As a contrast to this, the curve for the 6 inch Q.F. gun (Fig 2) shows a pressure which nowhere exceeds 15 tons on the square inch and which diminishes gradually towards the muzzle. We may also note how in each gun the shape or profile of the gun corresponds with the curve of powder-pressure.

Crusher Gauges.

To discover the amount of the pressure at different points in the bore by practical experiment, crusher-gauges are used.

An experimental gun is bored with holes say a foot apart all the way down, extending through into the bore. Into each hole is screwed a crusher-gauge, consisting essentially of a piston with a soft copper plug behind it. As the shell travels up the bore, each piston in turn is exposed to the pressure of the gases and forced back, compressing the plug behind it. By measuring the amount of the compression of each plug, the pressure to which it was exposed can be determined with remarkable accuracy.

Noble's Chronoscope.

The crusher-gauges affords a means of measuring the pressure at any point in the bore. To measure the velocity, the chronoscope is used.

Instead of the crusher-gauges, cutter plugs are inserted into the holes in the gun. Each plug has an electric wire passing through it, and a knife, of which the back projects into the bore. When the shell passes the plug, it forces in the knife and cuts the wire. This interruption of the circuit causes an electric spark to pass at another point in the circuit.

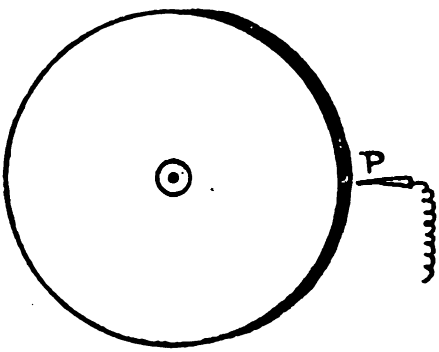


FIG. 3.

To record the instant at which this takes place, a brass disc some 30 inches in circumference is revolved at a great speed. The edge of the disc is smoked. Each interruption of current as the shell passes a cutter-plug causes a spark to pass between the point P and the disc, burning a hole in the coating of smoke-black. The velocity of rotation of the disc being known, it is only necessary to measure the distance between the marks left by the sparks to know the time that elapsed between them.

To avoid confusion, a row of discs fixed on the same axle, one for each cutter-plug, is used.

The Explosion Vessel.

The powder-pressure at any point within a gun may be determined by the use of crusher-gauges and cutter-plugs. But the explosion vessel enables the pressures to be determined more conveniently and with greater accuracy. It consists of a steel cylinder, bound with wire to strengthen it, closed by a screw plug. A given charge of cordite is placed in this and ignited electrically. The resulting explosion occupies an an appreciable time—say $\frac{1}{500}$ of a second—before the cordite is all consumed. A pressure-gauge is connected with the vessel, which records the rise of pressure during the time of explosion on a drum, in the same manner as a self-registering barometer. The

curve obtained on the drum is about 100 millimetres long, and can be read to 1 millimetre or less, giving the pressure for every $\frac{1}{10000}$ of a second. Knowing the capacity of the vessel, the rise of pressure in a gun of given calibre, the capacity of which alters as the shell travels up the bore, can be calculated mathematically.

Since the time which cordite takes to burn, at a given temperature and pressure, varies according to the thickness of the cord, it is possible to deduce, from results obtained with cordite of a given size, the size of cordite which will give suitable pressures in a certain gun.

This method of determining internal ballistics is due to Major J. H. Mansell, R.A.

The Boulengé Chronograph.

This instrument is used for measuring the velocity of the shell after leaving the muzzle. Two screens are placed one behind the other in the path of the shell, say 80 feet apart, and sufficiently far off to be clear of the blast of the gun. Each screen has an electric wire stretched backward and forwards across it so that when the shell passes through the screen the circuit is broken.

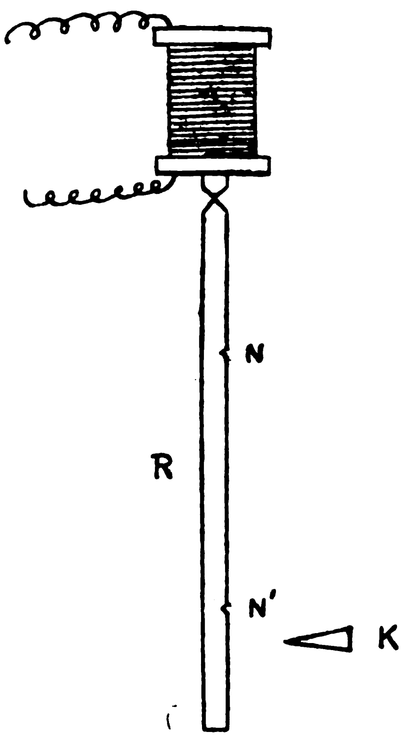


FIG. 4.

Let R be a rod suspended from an electro-magnet. When the shell passes the first screen the circuit is broken and the rod begins to fall. When the shell passes through the second screen the break of circuit releases the knife K, which makes a nick N on the falling rod. Since the force of gravity does not vary, the rod falls at the same speed every time, and it is only necessary to measure the distance of the nick up the rod with a suitable scale in order to know the time taken by the shell to travel from one screen to the other.

Disjunctor.

To allow for the time taken for the knife to act after the circuit is broken at the second screen, the disjunctor is used. This is simply a contrivance for breaking both screen-circuits simultaneously. The rod then falls a short distance before the knife has time to act, making a nick at N'. The distance NN' is thus the true measure of the time taken by the shell between the two screens. The distance up the rod of the nick N' is known as the *disjunctor reading*.

Sebert's Velocimeter.

This is a simple apparatus for measuring the velocity of recoil of a gun. A bristle fixed to a vibrating tuning-fork is made to brush against the smoked surface of a strip of steel attached to the gun. When the gun recoils, the bristle traces a wavy line on the smoked surface. Since we know the rate of vibration of the tuning-fork, it is only necessary to count the waves to determine the speed of recoil.

Thus if the wavy line be four feet long, it shows that the gun has recoiled through that distance. If the tuning-fork used vibrates 500 times per second, and 100 waves are counted on the smoked surface, then the gun took two-tenths of a second to recoil; if ten waves are counted on the first six inches of the line, then the recoil-velocity over the first six inches was 25 feet per second.

The Buffer-gauge.

The hydraulic buffer of a long-recoil gun is designed to produce a perfectly regulated resistance throughout the recoil. For the purpose of adjusting the pressure in the buffer, which constitutes the resistance to recoil, the buffer-gauge is used.

This consists in principle of a pressure-gauge in which an indicator is forced upwards against a spring. A special hollow piston-rod is inserted in the buffer and the gauge screwed on to the outer end of it. A long strip of smoked sheet metal is attached to the gun, so that as the gun recoils the indicator traces a line upon it. If the pressure is uniform during recoil, the indicator remains at the same height, and traces a straight horizontal line; if the pressure is irregular the indicator goes up and down, producing a wavy line. If this is found to be the case, the buffer must be regulated by altering the windage between buffer and piston at different points till the indicator traces a curve corresponding to the graduated pressure required. This, in practice, is effected by altering the depth of the channels or grooves in the inner walls of the buffer (called *ports*) through which the liquid flows past the piston.

A difference of $\frac{1}{100}$ inch in the depth of the ports is found to produce a marked difference in the steadiness of the gun.

CHAPTER II.

THE UNIMPEDED MOTION OF A PROJECTILE.

Suppose a shell to be fired in vacuo in a horizontal direction with a velocity of 1000 feet per second. Then its path will be determined by the two forces acting on it, namely, the impetus of the shell, which tends to carry it forward in the direction in whict it started; and the force of gravity, which tends to pull it down to the earth.

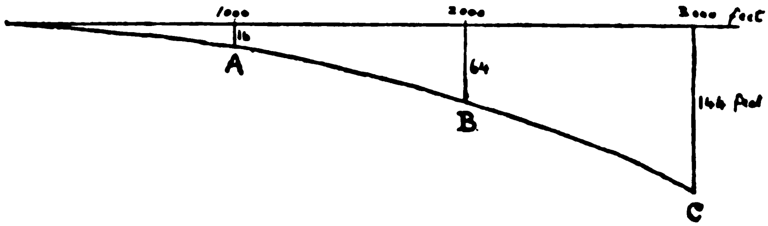


Fig. 5.

We know that a falling body drops (neglecting decimals), $\frac{1}{2}gt^2$, or—

$16 \times 1^2 =$	16 feet by	the end of the	first	second.
$16 \times 2^2 =$	64 ,,	,,	second	,,
$16 \times 3^2 =$	144 ,,	,,	third	,,
$16 \times 4^2 =$	256 ,,	,,	fourth	,,
$16 \times 5^2 =$	400 ,,	,,	fifth	,,

and so on.

Then by the end of the first second, the shell will have travelled 1000 feet forwards and have dropped 16 feet downwards, so that its position will be at A.

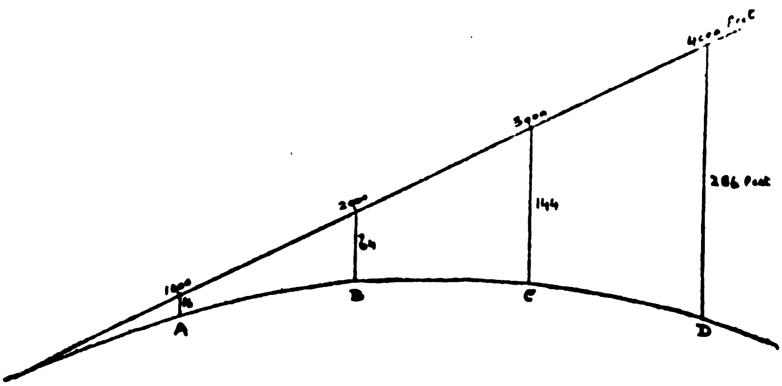


Fig. 6.

At the end of the next second it will have travelled another 1000 feet forward, and will have dropped altogether 64 feet, and its position will be at B; and so on.

The path A, B, C of the shell is called the *trajectory*.

If the shell could be fired in a vacuum, as is imagined in the preceding paragraphs, the curve of the trajectory would be a parabola. But in practice, as will be explained hereafter, the shape of the trajectory is considerably modified by the resistance of the air.

Shell fired vertically.

If a shell be fired straight up into the air, at a velocity of 1000 feet per second, it will continue to fly upwards until the ever-increasing downward velocity due to gravity exceeds 1000 feet per second, when it will begin to fall.

To work this out practically we must use the formula.

$$V = gt.$$

Where V is the velocity, g the *acceleration* due to gravity, and t the time in seconds. Now g is always the same, since the force of gravity does not vary, and is equal to 32 feet (strictly 32.2 feet) per second.

Some confusion may arise in the learner's mind between the 32 feet of acceleration due to gravity, and the 16 feet through which a body drops in the first second.

Now if a body falls from rest, it falls faster and faster, until at the end of the first second it is travelling at the rate of 32 feet per second. This acceleration of velocity from 0 to 32 feet per second is "g," and every unsupported body gets an extra velocity of 32 feet imparted to it by gravity every second. If the body be supported, then the effect of gravity is to cause a continuous stress on the support.

It will be apparent on consideration that the distance through which a body falls in the first second is not 32 feet, since the body only attains that velocity at the *end* of the second. The distance corresponds to the *mean* velocity of the body during that second, which is half-way between 0 and 32, or 16 feet.

To return to the question of the shell fired vertically upwards. As we have stated, $V = gt$, that is, for every second that the shell is in the air it acquires an increasing downward velocity of 32 feet. At the end of 10 seconds it will have acquired 320 feet per second downward velocity; but since its impetus continues to drive it upwards at 1000 feet per second, its actual remaining upward velocity will be 680 feet per second.

At the end of 30 seconds its downward velocity will be 960 feet, and at the end of 32 seconds, 1024; so that at some time in the 32nd second (actually at 31¼ seconds) the upward velocity will balance the downward velocity, and the shell will begin to fall again. Thenceforward the velocity will increase at 32 feet per second until the shell eraches the earth again.

Its velocity on reaching the earth will be $31\frac{1}{4} \times 32$, or 1000 feet per second, which we see is equal to that with which it started.

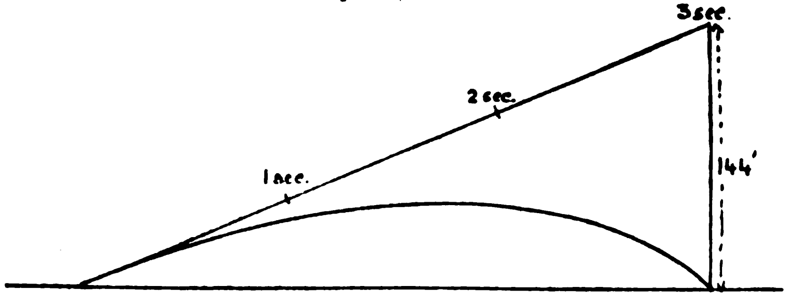


FIG. 7.

Elevation.

Since a shell is falling during the whole time of flight, then in order to reach the target it must be directed at a point above the target. The height of this point must be equal to the distance through which the shell falls during the time of flight.

Thus if the shell be fired at an object 3000 feet distant with a velocity of 1000 feet per second, it will take 3 seconds to reach the target. And since in 3 seconds the shell will fall $16 \times 3^2 = 144$ feet, therefore it must be directed at a point 144 feet above the target.

Since the parabola which a shell describes in vacuo is a regular curve, with its ascending and descending branches alike, the greatest height attained by the shell will be at a point half-way down the range.

For simplicity, we will take the case of a shell with a M.V. of 1000 feet and a time of flight of 4 seconds. Then point A at which the shell is aimed will be $16 \times 4^2 = 256$ feet above the target, and point C in the centre of the range will be 128 feet high. Half-way down the range the shell will have been falling two seconds, and will be 64 feet below C, or $128-64=64$ feet high. This is one-quarter of the height of A, and this proposition holds good for any shell describing a parabola.

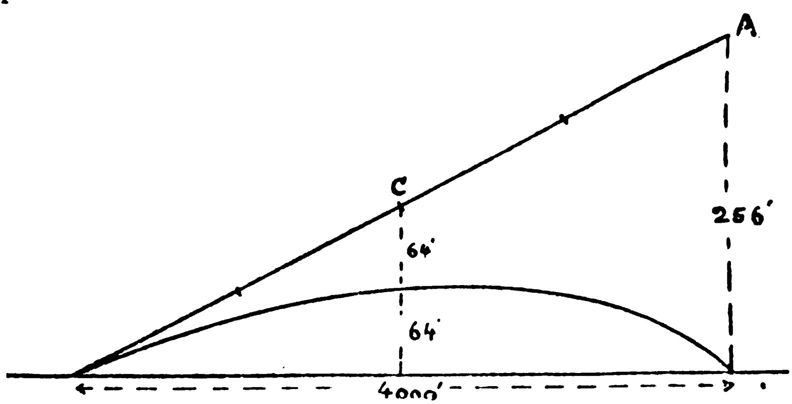


FIG. 8.

Since the height of A in feet is sixteen times the square of the time of flight, therefore the greatest height attained by the shell is four times the square of the time of flight, or

$$H = 4T^2.$$

This formula is given here because it is practically useful. At medium ranges the first half of the trajectory of a field gun fired under ordinary conditions is not very different from a parabola, and the formula is sufficiently near the truth for practical purposes. The time of flight is always known either from the range table or the fuze scale, and this give us a ready means of determining the height of the trajectory.

Flatness of Trajectory.

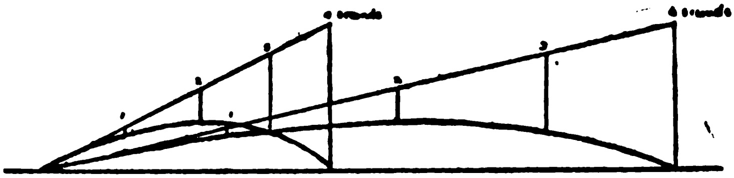


FIG. 9.

A shell which travels high above the earth to reach the target is clearly ineffective against an enemy standing anywhere except at the exact point where the shell pitches. On the other hand, a shell which flies along comparatively close to the ground will strike a six-foot man standing anywhere between the place where the shell pitches and the point where the trajectory comes within six feet of the ground. This space over which an enemy is liable to be struck by a projectile fired at a given point is called the ***dangerous zone***, and it is the object of the gun-designer to make this dangerous zone as deep as possible; not so much on account of the shell as on account of the shrapnel bullets which issue from it. This is secured by ***flatness of trajectory***—that is, by projecting the shell so that the height above the earth which it reaches is as small as possible.

High Velocity.

Now we have seen that it is necessary to project a shell to a certain height in order to reach a target in a given number of seconds. And no human power can alter the height through which a shell falls in a given time. To obtain a flat trajectory, therefore, all that we can do is to reduce the time of flight as much as possible.

If in the foregoing example the velocity of the shell were 3000 feet instead of 1000 feet per second, it would reach the target in one second, and the greatest height, $4T^2$, would be 4 feet. If the velocity were 1500 fs. the time of flight would be 2 seconds, and the greatest height 16 feet, giving a dangerous zone of about 200 yards in front of the target.

Thus we see that to procure a flat trajectory and deep dangerous zone we must have a high velocity, enabling us to use a small angle of elevation. When we consider the motion of projectiles in air we

shall find that another important consideration is a high proportion of weight of shell to cross section, which enables the shell to keep up a high velocity in spite of the resistance of the air.

Angle of Descent.

Flatness of trajectory is estimated in practice by the smallness of the angle of descent. The field gunner's object is to burst his shrapnel so that the bullets do not pitch straight downwards into the ground, but sweep along it, so as to produce good effect in spite of inevitable errors of range. For this he requires a small angle of descent, which is only possible with a high muzzle velocity.

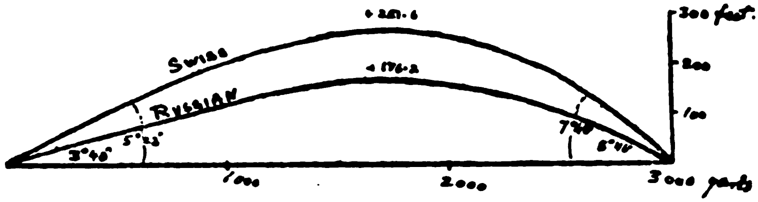


FIG. 10.

Figure 10 shews the trajectory of the Russian 1900 gun, firing a shell of 14.48 lbs. with M.V. 1930 fs., compared with that of the Swiss gun, shell 14 lbs. and M.V. 1590 fs. Figure 9 shews the effect of high and low muzzle velocity upon the trajectory for equal times of flight.

Greatest Possible Range.

The greatest possible range in vacuo is obtained when the angle of elevation is 45 degrees. When fired in air the angle giving the greatest range is not materially different, being between 40 and 43 degrees. Little is gained in range by increasing the angle of elevation beyond 35°.

CHAPTER III.

THE MOTION OF A PROJECTILE IN AIR.

A projectile travelling through the air experiences a certain resistance, which shortens the distance of its flight and alters the shape of the trajectory. This resistance is greater at high than at low velocities, but the rate of increase does not follow any simple rule.

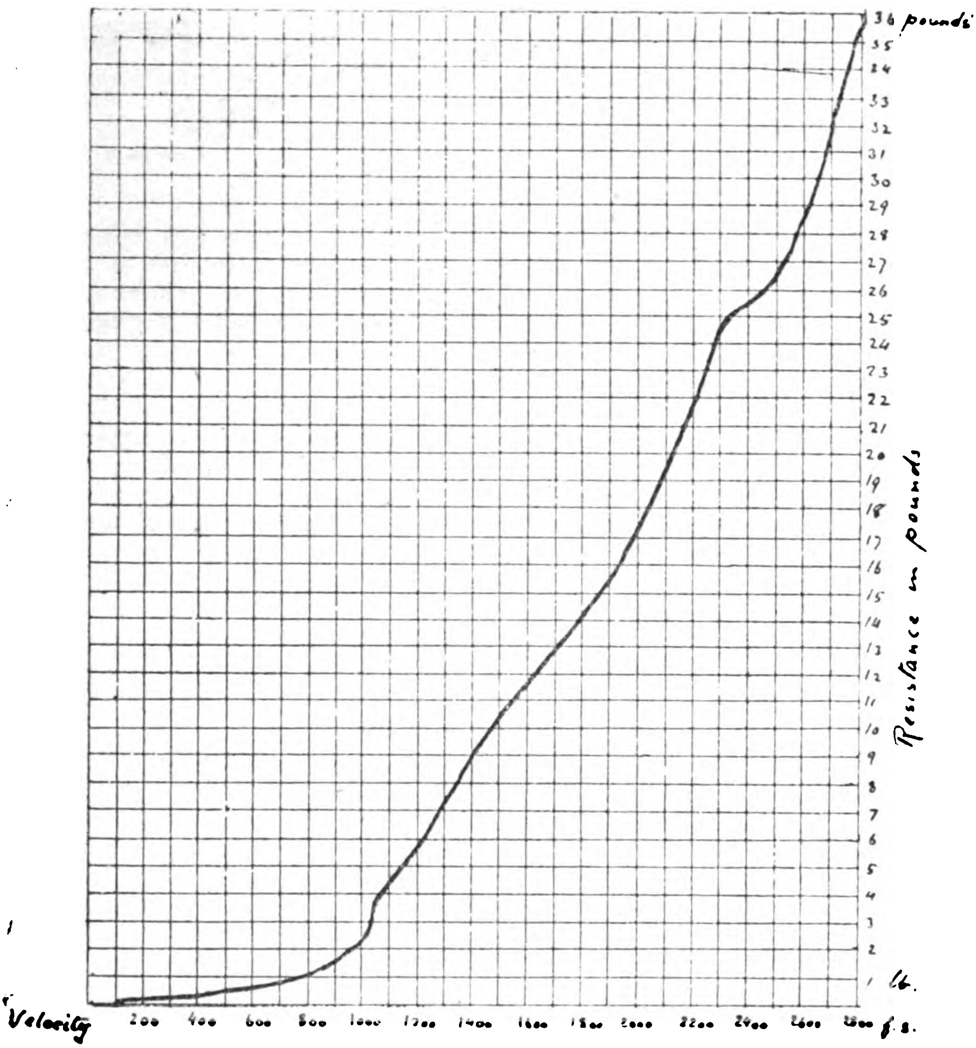


Table showing the resistance of the air to a projectile one inch in diameter.

Up to about 800 feet per second it increases as the square of the velocity; that is, a shell travelling at 300 feet per second experiences 9 times as much resistance as one travelling at 100 feet per second. Above 800 fs. the resistance increases in a higher ratio. For velocities between 1000 and 2500 feet per second the resistance may be said to increase roughly as the cube of the velocity.

The accompanying Table shows the resistance in pounds which the air offers to a projectile one inch in diameter, travelling at speeds from 0 to 2800 feet per second.

It will be observed that the increase of resistance is by no means regular. There is a marked kink in the curve between 1000 and 1150 fs., which latter figure happens to be the velocity of sound; and another remarkable kink about 2413 fs., the velocity at which air rushes into a vacuum. No scientific explanation of these phenomena is as yet forthcoming. It may be noted that if the shell is travelling at more than 2413 fs. it forms a vacuum behind it.

It will be readily understood that the resistance is in direct proportion to the surface offered to the air, that is to the cross section of the projectile. This is apparent, since two projectiles side by side, each one square inch in cross section, will experience twice as much resistance as one such projectile.

Shape of Head.

The resistance is affected in a marked degree by the shape of the head of the shell. It is found that in a shell of the usual form the shape of the shoulders is more important than that of the actual point. It is suggested as an explanation of this that as the air streams outward from the point to pass ever the shoulders of the shell it leaves a partial vacuum in front of the point, while the main air pressure comes near the shoulder. But when a shell with an ogive of 5 or 6 calibres radius is used, the shape of the point becomes important, as determining the stream lines, or direction of the currents of air which flow over the shoulders of the shell.

The figure shows various forms of head that have been experimented with.

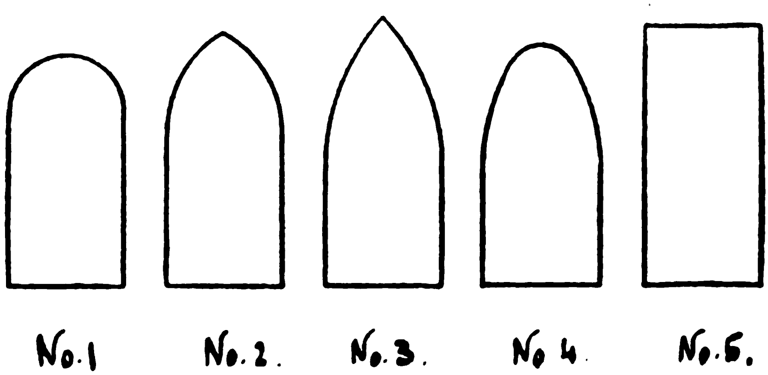


FIG. 11.

Taking the resistance offered to a shell with hemispherical head at 1 pound, it is found to be 0.83 lb. for No. 2, with a head struck with a radius of 1 diameter. 0.78 lb. for No. 3, radius 2 diameters, and the same for No. 4, which is No. 3 with the point rounded off. With No. 5, the flat-headed shell, the resistance is nearly double, or 1.53 lbs. The curve of resistance given in the table was obtained with the service shell of 35 years ago, having an ogival head struck with a radius of 1½ diameter.

Very remarkable results have recently been obtained with so-called pointed bullets and pointed shell, in which the cylindrical portion is reduced to a minimum and the projectile is nearly all point. It is possible by using very long points to reduce the resistance of the air by as much as 50 per cent. The reasons why this form has not been adopted for field shell are given in the chapter on Ammunition.

Smoothness.

It is also found that a modern smooth steel shell with driving-band meets with less resistance than the old cast-iron studded shell which were used in the 1879 experiments upon which our modern tables of resistance are founded. This requires a modification in the tabular figures for each different nature of shell.

Steadiness.

If a shell wobbles and travels shoulder first, its cross section is naturally larger, and the resistance it meets with greater, than if it travelled point first. Modern Q.F. shell are steadier in flight than B.L. and the old R.M.L., and another correction is required on this account.

Taper-base shell.

The ideal shape of a shell intended to travel through the air with the minimum of resistance is that of a Whitehead torpedo, with a long tapering "tail." Theoretically, the shape of the base is more important than that of the head—just as, in ship designing, a fine run is found even more conducive to speed than a sharp entrance. The flat sawed-off bottom of the service shell is objectionable for several reasons. It forms a partial vacuum behind it, causing an unbalanced air-pressure on the head of the shell, and the air rushing into this vacuum forms eddies which tend to unsteady the shell. It would therefore appear desirable to introduce a more scientific form of projectile. This idea was carried out successfully in the original Whitworth solid shot, which was the first accurate artillery projectile ever invented, But modern experiments have given less favourable results. The Zalinski torpedo shell, fired from an air-gun, had a habit of pitching in unexpected places. And at a trial carried out in Switzerland in 1903 it was found that although the taper-base shell ranged further than the ordinary pattern, they were decidedly inaccurate in flight. It would, however, be a mistake to condemn a theoretically sound design on the strength of a single experimental series. The failure of the Swiss experiments only showed that *something* was wrong—probably the twist of the rifling was unsuited to these particular shell. It is to be hoped therefore, that, in spite

of the obvious manufacturing difficulties, modern science may evolve a better shape of projectile than that of the cylindro-ogival shell which forms our present equipment.

Density of Air.

When the barometer is high, the air is compressed and is denser that when it is low; on the other hand, when the thermometer is high the air expands and is less dense than when the temperature is low. Since the resistance to a projectile is greater when the air is denser, the pressure and temperature must be taken into account in all accurate work, such as practice for range and accuracy.

Temperature.

Besides the effect of the temperature on the density of the air, it has another and practically much more important action, namely its effect upon the powder. All modern smokeless powders are comparatively sensitive to changes in temperature, and a rise in the thermometer usually means an increase of muzzle velocity. The amount of such increase varies for each particular size and sample of powder, and cannot well be tabulated.* For this reason in practice for range and accuracy at Shoeburyness the powder charges are carefully heated or cooled to a uniform temperature of 60° Fahrenheit.

* NOTE.—For effect of temperature on cordite, size 5, as used in field guns, see chapter on Ammunition.

CHAPTER IV.

BALLISTIC TABLES AND THEIR USE.*

In the foregoing chapter we have given a brief account of the influences which affect the flight of the shell through the air. In the present chapter we will show how the effect of these influences is calculated, in order to determine the path of the shell after leaving the gun. This knowledge is required in order to know the elevation and deflection which must be given to the gun in order to strike a given mark; or, conversely, in order to design a gun which will fulfil certain ballistic conditions, such as a given striking velocity, angle of descent, &c., at a given range.

In the Text Book of Gunnery will be found a set of eleven ballistic tables, by means of which any ordinary problem in gunnery may be readily solved. The use of these tables requires only the most elementary knowledge of mathematics. It is advisable however to use either the slide rule or the table of common four-figure logarithms in working out results, as otherwise the labour of multiplying and dividing will be found somewhat tedious.

The tables in the 1907 Text Book have now been replaced by "Ballistic Tables, 1909," which are published separately. The new tables are compiled from the result of recent experiments carried out by the Ordnance Board, and are more accurate and more complete than the old ones. They will be embodied in future editions of the Text Book. These are the tables to which reference is made throughout this Chapter.

It would be impossible to provide ballistic tables for every sort and size of shell. Accordingly the tables are all made out for a *unit projectile*, namely a shell weighing one pound, one inch in diameter, and with an ogival head struck with a radius of two diameters. By multiplying the results given by the tables by the ballistic coefficient referred to below, which is a sort of figure of merit of the shell, the tables can be made applicable to any projectile.

Table I gives the resistance of the air to the unit projectile, moving at any velocity.

Tables II to V are based upon Table I. They give respectively the time taken by the shell to drop from one velocity to a lower one, owing to the resistance of the air; the horizontal space through which it travels in so doing; the angle which its axis make with the horizontal plane; and its height above the ground at any point of the trajectory.

Table VI does not enter into the scope of this chapter.

Table VII is new, and is used in calculating the density of the air. The method of using it is described below.

*I have to express my thanks for the invaluable assistance afforded to me by Captain Maitland-Addison, Ballistic Officer, Royal Arsenal, in the compilation of this Chapter.
H.A.B.

Table VIII is compiled from Tables III, IV and V, and is a double-entry table. It is most useful for finding the elevation when the range is known, or *vice versâ*.

To apply these tables, certain simple formulæ are used, which are given below. Unfortunately our gunnery notation is just now in a stage of transition. Thus in the 1907 text book the formula used with the table for finding the range is written

$$s = C\,(S_V - S_v)$$

in the 1909 tables it is written

$$s = C\,[S\,(V) - S\,(v)]$$

while in the notation which is now generally used it becomes

$$x = C \left\{ S_V - S_u \right\}$$

Since the latter notation is employed in foreign text books, and will be employed in future English text books, it has been adopted in this chapter.

The symbols are as follows:—

x = the range in feet.

t = the time of flight in seconds.

ϕ = the inclination in degrees of the trajectory at the beginning of the arc to the line of sight.

θ = the inclination in degrees of the trajectory at the end of the arc to the line of sight.

(If the line of sight be horizontal, and if there is no jump, ϕ is the angle of elevation and θ the angle of descent.)

y = the height of the trajectory in feet at the point to which the range is x.

C = the ballistic coefficient.

$u = v \cos\theta \sec\phi$ = the pseudo-velocity at the end of the arc.

v = the real velocity at the end of the arc.

V = the muzzle velocity, either real or pseudo-velocity, because $\cos\phi \sec\phi$ equals unity, and therefore $V = V\cos\phi\sec\phi = V$.

The formulæ used with the tables are as follows:—

Table II	...	$t = C \sec\phi \left\{T_V - T_u\right\}$
Table III	..	$x = C \left\{S_V - S_u\right\}$
Table IV	...	$\tan\theta = \tan\phi - \dfrac{C}{\cos^2\phi}\left\{I_V - I_u\right\}$
Table V	...	$\dfrac{y}{x} = \tan\phi - \dfrac{C}{\cos^2\phi}\left\{I_V - \dfrac{A_V - A_u}{S_V - S_u}\right\}$
Pseudo Velocity		$u = v\cos\theta\sec\phi$

The method of using these formulæ is described below.

The Ballistic Coefficient.

Before the Tables can be applied to determine the trajectory of any particular shell, it is necessary to work out the ballistic coefficient. It has been shown in the last chapter that the power of overcoming resistance of the shell is inversely proportional to its cross section, that is to the square of its diameter, and we have no difficulty in understanding that it is directly proportional to its weight. Hence the power of the shell is well expressed by $\frac{w}{d^2}$, and w and d are the principal factors in the ballistic coefficient.

The power of the shell is also affected by its shape and smoothness, represented by the symbol κ (kappa), and by its steadiness in flight, represented by σ (sigma). Hence the figure of merit of the shell becomes $\frac{w}{d^2.\kappa.\sigma}$. For convenience of calculation, two other factors which have nothing to do with the shell are embodied in the ballistic coefficient; these are τ (tau) the correction for the tenuity of the air, both for the height above sea-level and the average height at which the shell travels; and β, known as Siacci's Beta function, which is a correction for certain inherent inaccuracies in the simplified formulæ with which the Tables are intended to be used.

Thus the complete ballistic coefficient becomes:

$$C = \frac{w}{d^2.\kappa.\sigma.\tau.\beta}$$

The factor of shape, kappa, is unity for a modern Q.F. shell with driving-band and with ogival head struck with a radius of two diameters, commonly referred to as a two-diameter or two-calibre head, which is the shape of the unit projectile for which the Tables are calculated. If the radius of the ogive be greater than two diameters, the resistance is diminished, and κ is less than unity. For example, κ is 0.72 for a shell with 4-calibre head, and 0.5 for an 8-calibre head. For a flat head κ is about 2.7, and about 2 for a proof cylinder, which has a flat head with radiused shoulders.

The factor of steadiness,* sigma, is practically unity for a modern gun so long as the trajectory is flat. At elevations over 20 degrees the trajectory becomes curved, and the shell has a tendency to become unsteady in the descending branch of the trajectory, requiring an increase in the value given to sigma. At very high angles of elevation, such as 45° and over, the shell, from the vertex downwards, travels at angle of some 20° to the trajectory, and gradually settles down into the tangent to the trajectory, so that it reaches the ground point first. If the shell loses the spin which keeps it steady, as explained in the chapter on Rifling, it may even turn over and fall sideways, enormously increasing the value of sigma. A good value for trajectories over 30° is about 1.2 for low-velocity high-angle guns such as field howitzers.

*It would be more logical to call this the factor of unsteadiness. But here, as elsewhere, current nomenclature is adhered to.

The factor of tenuity, tau, is inserted to allow for the varying resistance of the air. The denser the air, the greater the resistance which it opposes to the shell. The density of the air is affected by the barometric pressure at the place from which the gun is fired, which depends partly on the weather, partly on the height above sea-level; by the average height of the trajectory, which in practice is always taken at two-thirds of the greatest height; by the temperature of the air, as shown by the wet and dry bulb thermometers; and by the amount of moisture in the air. The standard density, at which tau is unity, is that existing when the barometer stands at 30 inches and the thermometer at 60 degrees Fahrenheit, the air being $\frac{2}{3}$ saturated with moisture. Under these conditions the air weighs 534.22 grains per cubic foot. The factor tau expresses the relation between the actual and the standard density; that is, if at a certain place and on a certain day the density of the air, at two-thirds of the greatest height of the trajectory, is nine-tenths of the standard density, then tau must be taken at 0.9.

Suppose for instance, the barometer stands at 28 inches, dry bulb thermometer 61° and wet bulb 55°. Then from Table VII, on looking opposite dry bulb 61°, and wet bulb 55°, we see that the weight of the air, for barometer 29 inches, is 515.2. Deduct the proportional part for 1 inch of barometer, taken from the same column of the inset table, and we have

$$515.2 - 18.1 = 497.1$$

Then, on the ground level,

$$\tau = \frac{497.1}{534.22}$$
$$= 0.9305$$

Suppose the time of flight 15 seconds; then the greatest height of the trajectory, $4t^2$, is 900 feet, and the average height 600 feet. Then to find the value af τ for a height of 600 feet, we use the formula

$$\tau_h = \tau_g\,(1 - .00003\ h)$$
$$\tau_{600} = .9305\ (1 - 00003 \times 600)$$
$$= .9305\ (1 - .018)$$
$$= .9305 \times .982$$
$$= .914$$

This formula gives accurate results up to 3000 feet. Instead of using it we may calculate τ for 600 feet directly, remembering that the barometer falls 1 inch for every 1000 feet of height, and the thermometer, on the average, falls 1° below the ground temperature for every 300 feet of height.*

Then at 600 feet above the ground we have: Barometer 27.4, dry bulb 59, wet bulb 53. From Table VII, the weight of the air is 488 grains, and τ is .914 as before.

*The *memoria technica* for this is "3 to 1 bar one."

It may be imagined that too much importance has been attached to the exact determination of the tenuity factor. But it will be seen that in the above example the diminished air-resistance makes a difference of 8.6 per cent in the ballistic coefficient. This is an amount which is too large to be neglected.

The Beta Function.

Finally, we have the factor β, which completes the ballistic coefficient. This is introduced to compensate for an erroneous assumption made in obtaining the gunnery formulæ. Up to 15° elevation, this assumption involves no appreciable inaccuracy, and β may be neglected. Over 15° the error becomes appreciable, but may be corrected by using the values of β here given.

TABLE OF THE BETA FUNCTION.

(This table is correct for velocities up to 800 fs. and may be used without serious inaccuracy for velocities up to 1200 fs.)

ϕ	β	ϕ	β	ϕ	β
10°	1.00	22°	1.05	34°	1.13
11°	1.01	23°	1.06	35°	1.14
12°	1.01	24°	1.06	36°	1.15
13°	1.02	25°	1.07	37°	1.16
14°	1.02	26°	1.07	38°	1.17
15°	1.02	27°	1.08	39°	1.18
16°	1.03	28°	1.09	40°	1.19
17°	1.03	29°	1.09	41°	1.21
18°	1.03	30°	1.10	42°	1.22
19°	1.04	31°	1.11	43°	1.24
20°	1.04	32°	1.12	44°	1.25
21°	1.05	33°	1.12	45°	1.26

Strictly speaking, all high-angle trajectories should be calculated in arcs, a method which is not within the scope of this elementary treatise. But by using the above values of the Beta function we may obtain a very good approximation by the ordinary method.

The Pseudo-Velocity.

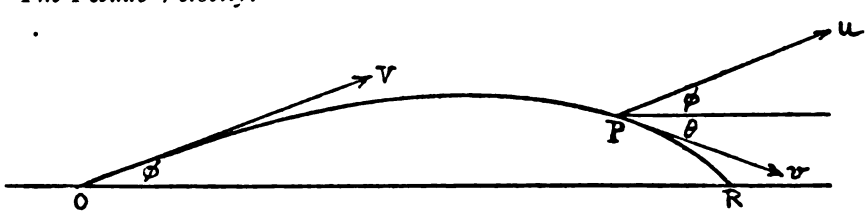


FIG. 12.

The formulæ used with Tables II to V tell us what happens to the shell—either as regards the time it takes, or the distance it travels, or the angle through which its direction changes—while the velocity drops from v, the muzzle velocity, down to u, the remaining velocity *measured parallel to the line of departure*. This latter is called the pseudo-velocity, while the velocity v, measured in the direction of the trajectory, is the real or actual remaining velocity. Now for flat

trajectories up to 3000 yards or so there is no very great difference between the real remaining velocity, as given in the range table, and the pseudo-velocity. Accordingly for rough calculations at short ranges we have merely to take the remaining velocity from the range table and insert it in place of (v) in the formulæ given at the head of the Tables. But for long ranges and curved or high-angle trajectories we must use more accurate methods.

From Fig. 12, by elementary trigonometry, we have:

$$u \cos \phi = v \cos \theta.$$
$$\text{or} \quad u = v \cos \theta \sec \phi.$$

In dealing with the muzzle velocity, we have no pseudo-velocity to consider, since the real muzzle velocity is of course equal to the muzzle velocity measured parallel to itself. But for every point of the trajectory except the muzzle we must use u, not v, in our calculations.

Example.

$$\phi = 10^\circ \qquad \theta = 15^\circ \qquad v = 1000 \text{ fs.}$$
$$u = 1000 \cos 15^\circ \sec 10^\circ$$
$$= 980.7 \text{ fs.}$$

There is one important formula which can be deduced from the altitude formula already given for use with Table V. If in this we put $y = 0$, and represent the function $2\left\{ I_v - \frac{A_v - A_u}{S_v - S_u} \right\}$ by the symbol "a," we get

$$\text{Sin } 2\phi = \text{Ca}.$$

Which is the formula used with Table VIII, which gives us the elevation required for any range. It is evident that when y, the height of the trajectory, is zero, the shell is either at the beginning or at the end of its flight. Consequently Table VIII gives us a direct connection between the angle of elevation and the range, without reference to the time of flight or remaining velocity.

Spherical Projectiles.

The table given in the Text Book of Gunnery, 1907, for spherical projectiles, (Table IX) has not been replaced by a new one, and is still used for calculating the ballistics of shrapnel bullets. But the new tables may be used with a suitable modifying factor. Thus if we take $C = \frac{w}{d^2}$ in the old table, then for the new tables $C = \frac{w}{d^2 \times 1.68}$ will give approximately the same result. It is found in practice that cast bullets, especially with resin adhering to them, require a value of kappa of about 1.04, which brings the modifying factor up to 1.75 nearly. Therefore the values of $\frac{w}{d^2}$ given in the Table at the end of this book should be divided by 1.04 for the old table or by 1.75 for the new tables.

Application of the Ballistic Formulæ.

For ordinary rough calculations, the ballistic formulæ already given can in many cases be considerably simplified. Thus for angles of elevation up to 15° the cosine and secant of ϕ and θ are very near to unity, and we may use the real velocity v in place of the pseudo-velocity u. The Beta function may be also taken as unity up to 15°. And for angles of elevation up to 5° the tenuity correction is negligible.

Example. Compute the ballistic coefficient for the 15 pr. Q.F. gun firing the original German ammunition, for an angle of elevation of 15 degrees.

We have

$$d = 3 \text{ inches} \qquad w = 14.3 \text{ lbs.}$$

κ = 1.00 (since the shell has a 2-diameter head)

σ = 1.15, (to allow for some unsteadiness towards the end of the trajectory.)

β = 1.02 by the table already given.

We have then only to calculate τ, the tenuity factor. Suppose that at the gun the barometer stands at 30″, dry bulb thermometer 60°, wet bulb 55°, giving the normal atmospheric density. From the range table, the time of flight is about 20 seconds, greatest height 1600 feet, and mean height 1066 feet. At this height the barometer will stand at 29 inches, dry bulb 57°, wet bulb 52°, and, from Table VII, the weight of the air will be 519.3 grains per cubic foot.

$$\text{Then } \tau = \frac{519.3}{534.22}$$
$$= .9725$$
$$\text{Then } C = \frac{w}{d^2.\kappa.\sigma.\tau.\beta}$$
$$= \frac{14.3}{9 \times 1 \times 1.15 \times .97 \times 1.02}$$
$$= 1.395.$$

(Note that the value of C given for the 15 pr. in earlier editions of this book referred to the old ballistic tables.)

For the same gun, at 3000 yards, κ, σ, τ and β may, for rough calculations, be taken at unity, and we have

$$C = \frac{14.3}{9}$$
$$= 1.59.$$

Example.

Compute the ballistic coefficient for the same gun firing Mark VI shell.

From the range table at the end of this book, we have

$$w = 14.1875 \text{ lbs.} \qquad d = 3 \text{ inches.}$$

The shell has a $1\frac{1}{2}$ diameter head, and we may take $\kappa = 1.25$. For standard atmospheric conditions, up to medium ranges, we take $\sigma = 1$, $\tau = 1$, $\beta = 1$. Then

$$C = \frac{w}{d^2.\kappa.\sigma.\tau.\beta}$$
$$= \frac{14.1875}{1.25 \times 9}$$
$$= 1.261$$

(ii.) Compute the range, given that

$$M.V. = 1674 \text{ fs.}$$
$$R.V. = 883 \text{ fs.}$$
$$C = 1.261$$

As we can employ the actual velocities in this case, we have

$$x = C\,\{S_V - S_v\}$$

and using Table III,

$$x = 1.261\,\{40099.2 - 32997.0\}$$
$$= 8956 \text{ feet.}$$
$$= 2985 \text{ yards}$$

which range agrees practically with that given in the Range Table, namely 3000 yards.

(iii). Compute the time of flight, given the same data as in the previous example.

We have

$$t = C\,\{T_V - T_v\}$$

and using Table II,

$$t = 1.261\,\{109.542 - 103.203\}$$
$$= 7.99 \text{ seconds}$$

which time of flight is also in fair agreement with that given in the Range Table, namely 7.93 seconds.

Example.

An entrenchment has to be constructed to afford protection from the fire of the German field gun at 3500 yards. Find the angle of descent of the shell.

We have first to find the ballistic coefficient. From the Table of Field Guns in Part IV of this book we find w = 15 lbs, d = 3.03 inches, M.V. = 1525 fs. The shell is of good modern design with a 2-calibre head. We may take kappa and sigma as unity, and at this range tau may be neglected. Then

$$C = \frac{15}{3.03^2} = 1.64$$

We next find the remaining velocity. At this range we may, without serious inaccuracy, take the real velocity as the same as the pseudo-velocity. Then, from Table III,

$$x = C\,(S_V - S_u)$$
$$10500 = 1.64\,(S_{1525} - S_u)$$
$$= 1.64\,(39418 - S_u)$$
$$S_u = 39418 - \frac{10500}{1.64}$$
$$= 33018.$$

By inspection of Table III,

$$u = 884 \text{ fs.}$$

We have next to find the angle of elevation from Table VIII.

$$\text{We have } R = 3500 \text{ yards (not feet,) } C = 1.64$$

$$\frac{R}{C} = 2136$$

In Table VIII, look up 2100 in the top line, and 1520 in the left hand column. Under 2100, and opposite 1520, we find the number 14648. Under 2200 we find 15626, difference 978; then for 2136 the number is $14648 + 9.78 \times 36 = 15000$. Similarly opposite 1530 we get 14866; the number required is half-way between the two, or 14933. This number is the function "a." Then we have

$$\begin{aligned} \text{Sin } 2\phi &= \text{Ca} \\ &= 1.64 \times 14933 \\ &= 24500 \end{aligned}$$

Then from the Table of Natural Sines in the log book:

$$\begin{aligned} 2\phi &= 14^\circ \ 11 \\ \phi &= 7^\circ \ 5' \ 30'' \end{aligned}$$

Or from the Table of Logarithmic Sines in the Text-Book of Gunnery:

$$\begin{aligned} \text{Log sin } 2\phi &= \log 24500 \\ &= 4.3892 \\ 2\phi &= 14^\circ \ 12' \\ \phi &= 7^\circ \ 6' \end{aligned}$$

We can now calculate the angle of descent from Table IV. We can use either of the formulæ at the head of the table, or the more accurate formula given at the beginning of this chapter. For our present purpose we will take the simplest formula, namely:—

$$\begin{aligned} \tan\phi - \tan\theta &= C\,(I_v - I_u) \\ \tan\theta &= \tan 7^\circ \ 6' - 1.64\,(I_{1525} - I_{884}) \\ &= .12456 - 1.64\,(.95354 - .77542) \\ &= .12456 - .292 \\ &= -\ .16744 \end{aligned}$$

The minus sign shows that the angle is a negative or downward one.

From the table of natural tangents,

$$\theta = 9^\circ \ 30'$$

If we add to this the semi-angle of opening of the shrapnel, then the angle of descent of the lowest bullets will be about $8^\circ + 9^\circ \ 30'$ or $17^\circ \ 30'$.

So that if we have to provide cover from shrapnel bullets for a 6-foot man standing 3 yards behind the parapet, the height of the crest will have to be

$$\begin{aligned} &6 + 9 \tan 17^\circ \ 30' \\ \text{or } &6 + 9 \times .315 \\ \text{or } &8.8 \text{ feet.} \end{aligned}$$

Example.

An Austrian gun has been captured, but the sights have been removed and it has to be layed by clinometer. Construct a range table for it.

From the table of field guns in Part IV, we find that the shell weighs 14.72 lbs, the calibre is 3.01 inches, and the M.V. is 1625 fs.

The simplest method is to calculate the elevation for ranges of 2000, 3000, 4000 and 5000 yards, plot these elevations on a curve, and thence measure the intermediate ranges and elevations.

Kappa, for a 2-diameter head, is unity; sigma (see p. 28) is 0.9; and at 2000 yards we may neglect tau, so that the ballistic coefficient is

$$\frac{w}{d^2} = \frac{14.72}{3.01^2 \times 0.9}$$
$$= 1.805$$

Then, by Table VIII,

$$\frac{R}{C} = \frac{2000}{1.805}$$
$$= 1110$$
$$a = 5130$$
$$C\,a = 9260$$
$$2\phi = 5^\circ\ 18'$$
$$\phi = 2^\circ\ 39'$$

Similarly for 3000 yards,

$$\phi = 4^\circ\ 59'$$

At 4000 yards we ought to decrease the ballistic coefficient to allow for some unsteadiness, and at 5000 yards the tenuity of the atmosphere, owing to the height of the trajectory, begins to affect the range. However for a field range table, used only as a basis for ranging, we may neglect these refinements. Adhering to the elementary formula, we get

$$\phi_{4000} = 7^\circ\ 33'$$
$$\phi_{5000} = 10^\circ\ 35'$$

Which gives us all the information necessary to use the gun against the enemy.

Example.

The time of flight of a shell fired from a Russian field gun, from flash to impact, is observed to be 9 seconds. Find the range.

From the Table of Field Guns,

$$w = 14.41 \text{ lbs},\ d = 3 \text{ inches},\ v = 1930 \text{ fs}.$$

The shell has a 2.75 diameter head, and kappa may be taken at 0.87.

Then the ballistic coefficient is

$$C = \frac{14.41}{9 \times 0.87} = 1.84$$

Now there is no formula directly connecting the time of flight with the range. We have first to find the remaining velocity. We may neglect the secant of the angle of elevation, as being practically unity, and we may take the real velocity for the pseudo-velocity, since the trajectory of the Russian gun at this range is very flat.

Then from Table II:

$$t = C\,(T_V - T_v)$$
$$12 = 1.84\,(T_{1930} - T_v)$$
$$T_v = 110.134 - \frac{12}{1.84}$$
$$v = 982 \text{ fs.}$$

From Table III:

$$x = C\,(S_V - S_v)$$
$$= 1.84\,(S_{1980} - S_{982})$$
$$= 1.84\,(41164 - 34902)$$
$$= 11500 \text{ feet}$$
$$= 3833 \text{ yards.}$$

Example.

The captain of a French field battery is ordered to open fire at a hostile battery 4000 metres distant. There is an intervening hill 175 metres high, half way down the range. Will his shell clear it?

Here we have $w = 15.95$ lbs, $d = 2.95$ inches, and $v = 1740$ fs.

The French shell has a 2-diameter head, so we may take $\kappa = 1$. There will be no serious unsteadiness at 4400 yards, and the tenuity coefficient may be neglected at this range for a gun with such a flat trajectory.

$$\text{Then } C = \frac{15.95}{2.95^2}$$
$$= 1.83$$

To find the height of the trajectory, we must first find the remaining velocity, and thence the time of flight.

From the Tables,

$$x = C\,(S_V - S_v)$$
$$3 \times 4400 = 1.83\,(S_{1740} - S_v)$$
$$S_v = S_{1740} - \frac{13200}{1.83}$$
$$= 40{,}386 - 7220$$
$$= 33{,}166$$
$$v = 891 \text{ fs.}$$

Then from Table II,

$$t = C\,(T_V - T_v)$$
$$= 1.83\,(T_{1740} - T_{891})$$
$$= 11.56 \text{ seconds.}$$

Then greatest height of trajectory is

$$h = 4t^2$$
$$= 535 \text{ feet}$$
$$= 163 \text{ metres}$$

Therefore the shell will not clear the hill, and the French captain must shift his battery to the rear so as to get a longer range, a more curved trajectory, and a sharper angle of descent.

If he shifts back 200 metres, his time of flight will be roughly in proportion, namely 12.1 seconds, and greatest height 178 metres, at a point 100 metres nearer with respect to the crest; this is cutting it rather fine, and he will do better to shift 300 metres back, and make certain of clearing the hill comfortably.

Example.

A French shrapnel bullet has a remaining velocity of 1000 fs. What will its velocity be at 300 metres from point of burst?

From the table at the end of this book, $w/d^2 = .095$. The French bullets are smooth, and we may take $\kappa = 1.02$. Then

$$C = \frac{.095}{1.02}$$
$$= .093$$
$$S_v = S_{1000} - \frac{x}{C}$$

From Table IX, Text Book of Gunnery,

$$S_v = 12424 - \frac{990}{.093}$$
$$= 12424 - 10625$$
$$= 1800 \text{ nearly}$$
$$v = 352 \text{ fs.}$$

Or if we use the new Tables, we have

$$C = \frac{.095}{1.02 \times 1.68}$$
$$= .0554$$
$$S_v = 35{,}207 - 17{,}890$$
$$v = 349 \text{ fs.}$$

The difference of 3 fs. between the results obtained shows that the modifying factor 1.68 is not strictly correct for all velocities.

Example.

Calculate the angle of elevation of the 18 pr. Q.F. for 3000 yards with Mark I shell.*

Given Barometer 30 inches, Thermometer 60° Fah. } $\tau = 1.00$.

κ for $1\frac{1}{2}$ calibre

radius of head $= 1.15$

$\sigma = .90$

$w = 18.5$ lbs.

$d = 3.3$ inches

*NOTE.—Throughout this book the figures referring to the ballistics of the 18 pr. are taken from the old range tables, compiled for Mark I shell. The present ammunition gives considerably better results.

(The value of 0.9 assigned to the sigma factor requires explanation. It must not be supposed that a value of unity for sigma implies perfect steadiness. The guns on the firing of which the new ballistic tables were based gave good results as regards steadiness, and for these guns a value of unity was assigned to the sigma factor. But the 18 pr. shell was afterwards found to be still steadier in flight, and to require a sigma factor of less than unity. This also applies to several of the newer foreign guns. In the absence of any exact information, it is advisable to take sigma as 0.9 for such guns as the Spanish and Portuguese Schneider guns, the Austrian gun, and the Italian Krupp.)

For such a flat trajectory β is unity.

$$\text{Then } C = \frac{18.5}{3.3^2 \times 1.15 \times .90} = 1.642$$

$$\frac{R}{C} = \frac{3000}{1.642} = 1830$$

From Table VIII, along the line, V = 1590 fs.

$$a_{1800} = 11087$$

$$a_{1900} = \frac{11952}{866}$$

$$a_{1880} = 11087 + \frac{30}{100} 865 = 11346$$

$$\text{Sin } 2\phi = Ca = 18630$$

$$2\phi = 10^\circ\ 44'$$

$$\phi = 5^\circ\ 22' \qquad \text{Official Range Table } 5^\circ\ 22'$$

To calculate the remaining velocity

$$x = C\{S_v - S_u\}$$

$$\text{or } S_u = S_v - \frac{x}{C}$$

From Table III,

$$S_{1590} = 39721.4$$

$$\frac{x}{C} = 5490.0 = \frac{9000}{1.642}$$

$$S_u = 34231.4$$

$$v = u = 945 \text{ fs.} \qquad \text{Official Range Table } 912 \text{ fs.}$$

To calculate the angle of descent

$$\tan\theta = \tan \frac{C}{\cos^2\phi}\left\{I_v - I_u\right\}$$

From Table IV

$$I_{1590} = .95757$$

$$I_{945} = .82244$$

$$.13513$$

$$\frac{C\{I_v - I_u\}}{\cos\phi} = \frac{1.642 \times .13513}{(.995)^2} = .22384$$

$$\tan\phi = .09394$$

$$\tan\theta = -.12990 \qquad \text{Official Range Table}$$

$$\theta = -7^\circ\ 24' \qquad 7^\circ\ 36'$$

The negative sign shows that we are dealing with the descending branch of the trajectory.

To calculate the time of flight,

$$t = C \sec \phi \{T_v - T_u\}$$

From Table III

$$T_{1590} = 109.309$$
$$T_{945} = 104.561$$

$$\Delta T \qquad 4.748$$

$$C \sec \phi \{\Delta T\} = 1.642 \times 1.004 \times 4.748$$

Official Range Table

$$\therefore \quad t = 7.80 \text{ secs.} \qquad 7.88 \text{ secs.}$$

To find the greatest height of the trajectory, a very good formula for flat trajectories is

$$y = 4t^2$$

Hence $y = 4 \times 7.8^2 = 264$ feet.

To find the velocity at the highest point of the trajectory:

At the summit the velocity is horizontal, so that $\theta = 0°$

$$\text{Hence} \quad \tan \theta = \frac{C}{\cos^2 \phi} \left\{ I_v - I_{u_0} \right\}$$

$$\text{or } \sin 2\phi = 2C \left\{ I_v - I_{u_0} \right\}$$

$$\text{or } I_{u_0} = I_v - \frac{\text{Sin } 2\phi}{2C}$$

$$I_{1590} = .95757$$

$$\frac{\text{Sin } 2\phi}{2\,C} = \frac{.1862}{2 \times 1.642}$$

$$I_{u_0} = .90087$$

$$u_0 = 1110 \text{ fs.}$$

RANGE TABLES.

The official range tables are calculated from additional ballistic tables not given in the Text Book of Gunnery, as they are too bulky. These extra tables greatly facilitate calculation. Exactly the same results may be arrived at with the published Tables, but with more labour. As an example we give here the complete calculation for the 13 pr. Q.F. with the 14½ lb. shell. As will be seen, the calculations have to be repeated until no change in the results is obtained.

In the official range tables all the calculations are very rigidly performed, to ensure great accuracy.

Example.

13 pr. Q.F.

Given $V = 1560$ fs.

$\phi = 8° \, 30'$

$w = 14.5$ lbs.

$\sigma = 1.04.$

Calculate i. The range

ii. Remaining velocity

iii. Angle of descent

iv. Time of flight.

We must first of all work out the problem, ignoring the correction for altitude, and then, having found the height, find the value of τ_h and re-calculate.*

i. The formula to be used with Table VIII is

$$\text{Sin } 2\phi = \text{Ca}$$

In this case we have $\tau_g = 1.00 \quad \beta = 1.00 \quad \kappa = 1.00$

$$\text{Then C} = \frac{w}{d^2.\kappa.\sigma.\tau.\beta}$$

$$= \frac{14.5}{1.04 \times 9}$$

$$= 1.55$$

$$\text{Also } \phi = 8^\circ\ 30'$$

$$2\phi = 17^\circ$$

$$\text{L Sin } 2\phi = 9.46593$$

$$\log C = 0.19033$$

$$\log a = 9.27560$$

$$a = .18863$$

In Table VIII, opposite $V = 1560$ fs, we find:

$$a = 18{,}100 \quad \frac{R}{C} = 2500$$

$$a = 19{,}156 \quad \frac{R}{C} = 2600$$

Hence for $A = 18863$, we have

$$\frac{R}{C} = 2500 + \frac{763}{1056}.100$$

$$72.3$$

$$= 2572.3$$

$$\log \frac{R}{C} = 3.41032$$

$$\log C = 0.19033$$

$$\log R = 3.60065$$

$$R = 3987 \text{ yards or}$$

$$x = 11961 \text{ feet.}$$

ii. To find the remaining velocity

$$x = C \{S_v - S_u\}$$

$$\text{or } S_u = S_v - \frac{x}{C}$$

*It is hardly necessary to say that τ_g means the tenuity at the ground level, and τ_h the tenuity at the mean height of the trajectory.

$$\log x = 4.07777$$
$$\log C = 0.19033$$
$$\overline{3.88744}$$
$$\frac{x}{C} = 7716.9$$
$$S_{1660} = 39582.5$$
$$\overline{S_u = 31865.6}$$
$$u = 833 \text{ fs.}$$

iii. To find the time of flight:

$$t = C \sec \phi \, \{T_v - T_u\}$$

We can put sec 8° 30′ = unity;

$$T_{1560} = 109.221$$
$$T_{833} = 101.882$$
$$\overline{\Delta T = 7.339}$$
$$\log 7.339 = 0.86564$$
$$\log C = 0.19033$$
$$\overline{\log t = 1.05597}$$
$$t = 11.37 \text{ seconds}$$

To find the greatest height, we should find the velocity at the vertex by means of Table III, calculate the range to this point by Table IV., and then calculate y by Table V.

But for flat trajectories the formula:

$$y = 4t^2$$

gives very accurate results.

$$\text{Hence } y = 4 \times 11.37^2$$
$$= 517 \text{ feet.}$$

To find τ_h, we have

$$\tau_h = \tau_g (1 - .00003 \, h)$$
$$= \tau_g (1 - .00002 \, y)$$

since the average height is ⅔ of the greatest height;

$$\tau_h = 1 - .01034$$
$$= .98966 = .99$$

And this value should be inserted in the denominator of the ballistic coefficient and the problem worked out again.

The second calculation will be found to give a range of close on 4000 yards, which agrees with the range table.

iii. The angle of descent works out to 12° 5′ (Range table value.)

iv. The time of flight works out to 11.49 seconds, inserting the value of sec ϕ (which was previously omitted) in the formula

$$t = C \sec \phi \, \{T_v - T_u\}$$

APPLICATION OF BALLISTIC TABLES TO HOWITZER FIRE.

Problems in howitzer fire can be solved in exactly the same way as those in direct fire, by the formulæ already given. Strictly speaking all such trajectories, as also those above 15° elevation, should be calculated by arcs, but the labour involved is great, and good accuracy can be obtained by a calculation in one arc, with the use of the coefficient β, which is very accurate for low velocities. The example given below shows how such calculations may be carried out.

Example.

Compute the ranges for the 6″ B.L. Howitzer, 100 lb. shell.

$$\begin{aligned} &\text{Elevation} = 40^\circ \\ &\text{M.V.} \quad = 690 \text{ fs.} \\ &\tau_g \quad = 1.00 \\ &\sigma \quad = 1.00 \\ &\kappa \quad = 1.00 \end{aligned}$$

The value of β required is 1.19 (*vide Table.*)

For the purpose of getting τ_h we may, without much error, take an approximation to the parabolic height. This is given by:

$$y = \frac{v^2 \sin^2 \phi}{2g}$$

$$\begin{array}{llll} \log \sin 40^\circ = 9.80807 & & \log 2 = & .30103 \\ \log v \quad = \underline{2.83885} & & \log g = & \underline{1.50773} \\ \quad 2.64692 & & & 1.80876 \\ \quad \underline{\quad 2} & & & \\ \quad 5.29384 & & & \\ \quad \underline{1.80876} & & & \\ \log y = 3.48508 & & & \\ \quad y = 3056 \text{ feet} & & & \end{array}$$

Hence we may take 2800 feet as fairly near the the correct height, and thus

$$\begin{aligned} \tau_h &= \tau_g (1 - .00002\, y). \\ &= 1 - .056 \\ &= .944 \end{aligned}$$

Therefore, computing C, we have

$$C = \frac{w}{d^2 .\, \kappa .\, \sigma .\, \tau_h}$$

$$= \frac{100}{1.19 \times .944 \times 36} = 2.48$$

Now $\quad \sin 2\phi = Ca.$

$$\begin{aligned} (\text{Since } \phi = 40^\circ), \quad L \sin 2\phi &= 9.99335 \\ \log C &= \underline{.39445} \\ \log a &= 9.59890 \\ a &= .39710 \end{aligned}$$

For M.V. 690 fs., Table VIII:

$$\frac{R}{C} = 1600 \qquad a = 39146$$

$$\frac{R}{C} = 1700 \qquad a = 42125$$

$$\overline{\quad 100 \qquad\qquad 2979}$$

$$\text{Hence } \frac{R}{C} = 1600 + \frac{564}{2979}.100$$

$$\begin{array}{r} 18.9 \\ \hline 1618.9 \end{array}$$

$$\log\frac{R}{C} = 3.20922$$

$$\log C = .39445$$

$$\log R = 3.60367$$

$$R = 4015 \text{ yds.}$$

Range Table gives about 4080 yds.

As there is only a difference of 100 yds. in range for a difference of 5° from 35° to 40°, the above calculation is a very fair estimate of the range. By making an approximation to y by the parabolic theory, a very near value to τ_h is obtained, and thus the labour of repeating all calculations is avoided.

The time of flight, remaining velocity, etc., etc., can be found as shown in the previous examples of direct fire, but as the actual remaining velocity will differ considerably from the pseudo-velocity, care must be taken to use the latter.

Example.

Find the M.V. required with a 3.5 inch mountain gun firing a projectile 22.5 lbs. in weight, to obtain a range of 5000 yards, with an elevation of 38°.

It is interesting here to calculate what M.V. would be required in vacuo to give the range. It further serves the purpose of getting the approximate correction to τ, for the altitude of the trajectory.

The velocity in vacuo is given by

$$v^2 = \frac{g\,x}{\sin 2\phi}$$

$$\text{and} \qquad v = 705 \text{ fs.}$$

To find the height of the parabolic trajectory, we have

$$y = \frac{v^2 \sin^2\phi}{2g}$$

giving $y = 2930$ fs.

Hence we can take about 2700 feet for the height in the air.

Taking τ_g as unity, we get

$$\begin{aligned} \tau_h &= \tau_g\,(1 - .00002\,y) \\ &= 1 - .054 \\ &= .946 \end{aligned}$$

Now β for $38^\circ = 1.17$. Taking $\kappa = 1.0$ and $\sigma = 1.0$, we have

$$C = \frac{w}{\beta.\ \kappa.\ \sigma.\ \tau_h.\ d^2}$$
$$= \frac{22.5}{1.17 \times .946 \times 3.5^2}$$
$$= 1.67$$

We now proceed to calculate "a" from Sin 2ϕ = Ca, and then, knowing "a" and $\frac{R}{C}$, we get the required M.V. from inspection of Table VIII.

$$\begin{array}{rlrl} L\ \text{Sin}\ 2\phi = & 9.98690 & \log R = & 3.69897 \\ \log C = & .22272 & \log C = & .22272 \\ \hline \log a = & 9.76418 & \log \frac{R}{C} = & 3.47625 \\ a = & .58100 & \frac{R}{C} = & 2994 \end{array}$$

By inspection, we find that the required M.V. is about 833 fs. Assuming that the mountain gun had been fired from a height of 2000 feet above sea level, the barometer, neglecting local variations, would have gone down about 2 inches, and would be about 28 inches. The temperature would not necessarily have fallen, since this is affected by the height above the ground, not the height above sea-level.

$$\tau_g = \frac{28}{30} = \frac{1000}{1000 + 2\,(T - 60)}$$
$$= .933$$

And
$$\tau_h = .933\,(1 - .00002\ y)$$
$$= .933\,(1 - .054)$$
$$= .933 \times .946$$
$$= .881$$

so that
$$C = \frac{22.5}{1.17 \times .881 \times 3.5^2} = 1.785$$

This, working on the same principle as before, gives the requisite M.V. as 822 fs. approximately.

It will be noticed that Table VIII does not cover velocities below 500 fs., but, with very fair accuracy, we can put

$$\text{Sin}\ 2\phi = Ca \left(\frac{500}{v}\right)^2$$

for velocities below 500 fs.

Example. Calculate the range for a gun whose complete ballistic coefficient is 2, M.V. = 300 fs., $\phi = 25^\circ$.

Here
$$a = \frac{\sin 2\phi}{C}\left(\frac{v}{500}\right)^2$$

$$\begin{array}{rlrl} L\ \sin 2\phi = & 9.88425 & \log C = & .30103 \\ 2 \log 300 = & 4.95424 & 2 \log 500 = & 5.39794 \\ \hline & 4.83849 & & 5.69897 \\ & 5.69897 & & \\ \hline \log a = & 9.13952 & & \\ a = & .13789 & & \end{array}$$

From Table VIII: $\frac{R}{C} = 341.6$

(opposite v = 500) $R = 341.6 \times 2$

$= 683$ yards.

By the parabolic theory, the range would be 714 yards. This shows the near approximation at low velocities.

Without involving much error the value of β given in the table on p. 20 can be used for velocities up to about 1200 fs.

For high angle fire at velocities above this point, the trajectory should be calculated in arcs, putting $\beta = \sec \phi$, when ϕ is the elevation at the beginning of each arc.

But even putting $\beta =$ unity, a very fair approximation can be made in one arc.

CHAPTER V.

ACCURACY OF FIRE.

However perfectly a gun may be layed, we never get two successive rounds to fall in the same place. This is due to several causes. In the first place, the muzzle velocity varies from round to round, owing to irregularities in the burning of the cordite and the resistance of the driving band. Next, the varying jump of the gun and carriage causes errors in elevation. And if the carriage be on a lateral slope, or if one wheel be on bad ground, the jump causes errors of direction as well.

In the next place, the shell rarely comes out of the muzzle quite straight, but usually with its nose pointing somewhat away from the line of departure, and revolving round it. This causes the shell to describe a preliminary helix or corkscrew curve round the mean trajectory. The amplitude of this helix tends to decrease under the influence of the resistance of the air, till at about 1000 yards the shell begins to settle down to a regular curve. In the same way a spinning top, after a first period of wobbling, "goes to sleep," and remains steady till its spin is insufficient to overcome the overturning moment due to the irregular frictional resistance of its point.

A further important cause of inaccuracy is defective manufacture. If the wall of the shell be thicker at one side than the other, the centre of gravity will not be in the axis of the shell, and its rotation will cause the shell to describe a helix of increasing diameter, which the resistance of the air will do nothing to check.

Besides these sources of error, the flight of the shell will be affected by the varying wind which it happens to encounter.

The practical result is that the trajectories of a number of shell fired from the same gun at the same elevation form a bent cone, which is called the **SHEAF OF FIRE.**

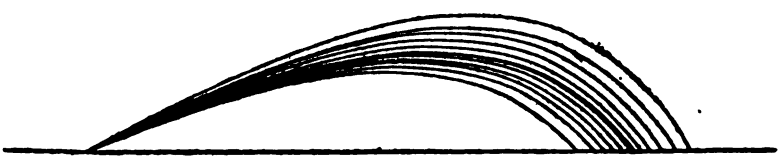
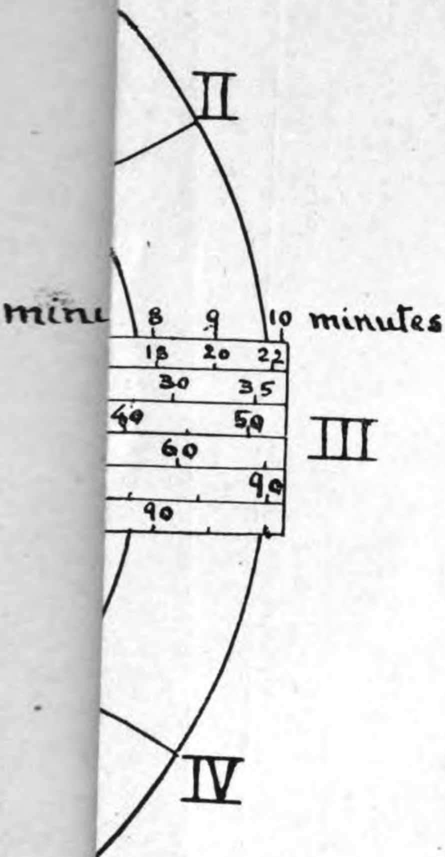


FIG. 13.

The intersection of the surface of the ground with the sheaf of fire forms an ellipse, of which the breadth is equal to the diameter of the cone, while the length increases with the smallness of the angle of



ind, and read off the

descent. If the cone were circular in section, then at an angle of descent of 30 degrees the length of the ellipse would be twice the breadth, while at $5^\circ 45'$ it would be just ten times the breadth. Since however the disturbing influences which affect the range (such as the variable jump of the carriage) are greater than those affecting the direction, the ellipse is usually found to be longer in proportion to its breadth than it would be if the vertical and horizontal errors were equal. The actual dimensions of this ellipse for each gun and for each range are determined by "practice for range and accuracy" at Shoeburyness. This practice is conducted with the utmost care, and all disturbing elements are as far as possible eliminated or corrected. Each shell and cartridge are weighed, the powder is kept at a uniform temperature, and the force and direction of wind noted for each round. The result is to give the dimensions of the area of ground upon which all shell fired at a given elevation and direction should fall.

Total Rectangle. For convenience it is usual to express this area in terms of the circumscribed rectangle. Thus instead of saying that all rounds fired from the 18 pr. Q.F. at 3000 yards are contained in an ellipse 80 yards long by $5\frac{3}{4}$ yards wide, we say that the *total rectangle* is 80 yards long and $5\frac{3}{4}$ yards broad.

Vertical Rectangle. Knowing the horizontal rectangle, it is easy to determine the dimensions of the vertical rectangle which all shots should strike. The height of this is approximately equal to the length of the total horizontal rectangle multiplied by the tangent of the mean angle of descent.

Battery Rectangle. When six guns are firing at the same target, they always make a bigger rectangle than one gun. For we have now to contend with additional sources of error, the principal being the different sighting of the six guns and the different personal error of the six layers. In practice, when the target is clearly defined, the total error should not be more than 25% greater than that obtained at Shoeburyness. If the rectangle be twice as long, it shows bad laying or neglected equipment.

The Fifty Per Cent. Zone.

If we direct a shower of shells from a gun, or a shower of pebbles from the hand, at a given mark, it will be found that these are not uniformly distributed over a space of ground, but lie more thickly towards the centre of the space. It can be demonstrated by the Theory of Probability that if the whole of the shell fall in a space 100 yards long, half of them will (on the average) be found within one quarter of that length, or 25 yards. Exactly the same result will be obtained if we measure the distance of each shell from the central one of the group, and multiply the *average* distance by the factor 1.69, which depends on the Theory of Probabilities.

Similarly, the width of the rectangle containing half the shell is one quarter of the width of the total rectangle, and the height of the

rectangle containing half the shell is one quarter of the height of the total rectangle.

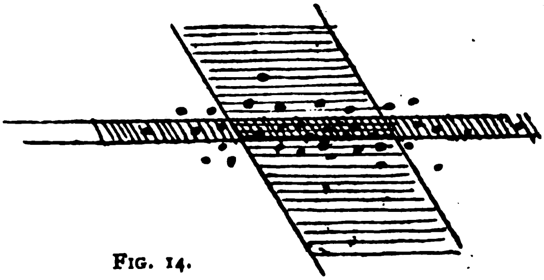


FIG. 14.

The Twenty-Five Per Cent. Zone.

Suppose all the shell to fall within a space 100 yards long by 4 wide. Then a tranverse zone or belt 25 yards in depth will include 50% of the shell. Similarly a longitudinal zone 1 yard wide will include 50% of the shell.

The central rectangle where the two zones are superposed will then contain 50% of 50% or 25% of the shell. If in the same instance all the shell fall within a vertical height of 12 yards, 50% will be in a vertical zone 3 yards high, and 25% in a vertical rectangle 3 yards high and 1 yard broad.

Probability of Hitting.

Knowing from the range table, the depth, width, and height of the 50% zone for any range, the table of Probability Factors enables us to determine the chance of hitting an object of a given size.

TABLE OF PROBABILITY FACTORS.
(From Mackinlay's Text Book of Gunnery.

The following gives the proportional width of other zones (çontaining a different percentage of hits) to one of 50% as unity

Per Cent.	Factor.	Per cent.	Factor.	Per cent.	Factor.	Per cent.	Factor.	Per cent.	Factor.
1	0.02	**21**	0.40	**41**	0.80	**61**	1.27	**81**	1.94
2	0.04	**22**	0.41	**42**	0.82	**62**	1.30	**82**	1.98
3	0.06	**23**	0.43	**43**	0.84	**63**	1.33	**83**	2.03
4	0.07	**24**	0.45	**44**	0.86	**64**	1.36	**84**	2.08
5	0.09	**25**	0.47	**45**	0.89	**65**	1.39	**85**	2.13
6	0.11	**26**	0.49	**46**	0.91	**66**	1.42	**86**	2.18
7	0.13	**27**	0.51	**47**	0.93	**67**	1.45	**87**	2.24
8	0.15	**28**	0.53	**48**	0.95	**68**	1.48	**88**	2.30
9	0.17	**29**	0.55	**49**	0.98	**69**	1.51	**89**	2.37
10	0.18	**30**	0.57	**50**	1.00	**70**	1.54	**90**	2.44
11	0.20	**31**	0.59	**51**	1.02	**71**	1.57	**91**	2.52
12	0.22	**32**	0.61	**52**	1.04	**72**	1.60	**92**	2.60
13	0.24	**33**	0.63	**53**	1.07	**73**	1.64	**93**	2.69
14	0.26	**34**	0.65	**54**	1.09	**74**	1.67	**94**	2.78
15	0.28	**35**	0.67	**55**	1.12	**75**	1.71	**95**	2.91
16	0.30	**36**	0.70	**56**	1.14	**76**	1.74	**96**	3.04
17	0.32	**37**	0.72	**57**	1.17	**77**	1.78	**97**	3.22
18	0.34	**38**	0.74	**58**	1.19	**78**	1.82	**98**	3.45
19	0.36	**39**	0.76	**59**	1.22	**79**	1.86	**99**	3.82
20	0.38	**40**	0.78	**60**	1.25	**80**	1.90	**100**	

Example 1.

Suppose we are firing with the 18 pr. Q.F. at 3000 yards; what is the chance of hitting a shielded gun 5′ high and 6′ wide?

From the Range Table,

50% of rounds should fall in 1.44 yards breadth, and 20 yards length. At an angle of descent of 7° 36′, or 1 in 7½, 7½ yards horizontal corresponds to 1 yard vertical, or 20 yards of length to $\frac{20}{7.5}$ or 2.667 yards of height.

Here the width of the target is two yards, or 1.4 times 1.44 yards. In the table, the factor nearest to 1.4 is 1.39, which we find opposite 65 per cent. That is, 65 per cent. of the shots will be correct for line.

The height of the target is 5 feet, or 0.625 times 4.7 yards. Factor 0.63 is opposite 33 per cent: therefore 33 per cent. of the shots will be correct for elevation.

33 per cent. of 65 per cent. is 21.66 per cent., that is, it will take

Page 39.—With the present ammunition the shooting of the 18 pr. is better than in the examples given. The gun will now make 16% of hits on a gun-shield 4 ft. 6 ins. high, by 5 ft. wide at 3000 yards.

Example 2.

What is the chance of dropping a shell into a rectangular gun emplacement 3 yards wide and 5 yards from front to rear, with the 18-pr. Q.F. at 3500 yards?

Assume the parapet revetted vertical, and 3′ high. Then since angle of descent (from range table) is about 1 in 6, a parapet 1 yard high will cover 6 yards to the rear, and it will be impossible to get a shell into the emplacement without going through the parapet. Suppose that a shell striking the superior slope within one yard of the crest will penetrate the parapet, then our target is reduced to a surface 3 yards wide by one yard from front to rear.

Now the 50% rectangle of the 18 pr. Q.F. at 3500 yards is 1.75 yards wide; 3 yards over 1.75 yards is 1.7, which factor we find opposite 75% in the Table, so that 75% of the shots will be correct for line.

Again, the 50% rectangle of the 18 pr. Q.F. at 3500 yards is 26 yards long; 1 over 26 is .038, or just short of factor .04 in the table, so that 2% of the shots will be correct for elevation;

2% of 75% is 1.5% nearly.

So that in 100 shots, under ideal conditions, we may expect to put 1.5 effective shell into the emplacement.

Example 3.

The battery is being fired at by the 75 mm. French gun at 4200 yards. Is the wagon less likely to be struck if placed alongside the gun or if placed behind it?

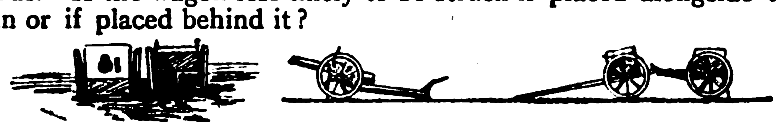


FIG. 15.

For the French gun, at this range, the 50% zones may be taken as under—

Longitudinal	...	32 yards
Lateral	...	1.5 „
Vertical	...	5.3 „

Consider first the chance of hitting the wagon alongside the gun. Suppose the enemy's fire directed at the gun. Then the wagon extends to a distance of about 9 feet from the centre line of the gun; if there were a wagon on each side the total width of the target would be 18 feet or 6 yards. This is just four times the 50% lateral zone, so that all the shell would be correct for line. The proportion which would hit one wagon alongside the gun is half the total less half the number which would hit the gun. The latter number corresponds to the probability factor $\frac{2}{1.5}$ or 1.33, obtained by dividing the width of the gun by that of the 50% zone, and is found by the table to be 63%. Therefore the percentage which would hit the wagon, as far as line goes, is $\frac{100-63}{2}$ or 18½%. Next for the elevation. The angle of descent being 1 in 6, we find by graphical construction that the effective height of a wagon limbered up is about 6 feet. That is, if a screen 6′ high were placed in front of the wagon limber, any shell passing through the screen would either hit the wagon limber or the wagon body or the ground underneath. Now suppose the range accurately found, so that the mean point of impact corresponds with the point of aim, that is, the ground line of the target. Then the 50% zone being 5.3 yards high, or 2.65 yards above and below the mean point of impact, the probability factor is $\frac{2}{2.65}$ or .755 and the percentage opposite to it is 39, so that 39% of the shots above the ground line, or 19½% of the whole, would be correct for elevation as regards the wagon. 19½% of 18½% is 3.61% which is the percentage of shots which would hit the wagon.

The above calculation is useful as a theoretical example, but is not practical. On service the gun-layer would naturally aim not at the gun but at the centre of the ground line of the group formed by gun and wagon. Taking the total width at 12 feet, it follows by a similar calculation that $\frac{93}{2}$ = 46½% of the shots would be correct for line as regards the wagon; multiplying this by 19½% as before we get 9.1% as the percentage of shots which would strike the wagon. But in this case the percentage which would strike the gun, which is only 5′ high measured at right angles to the trajectory, is less than half of the total hits, roughly in the proportion of 5 to 6, giving 7.6% only.

Next we take the case of the wagon placed behind the gun. In

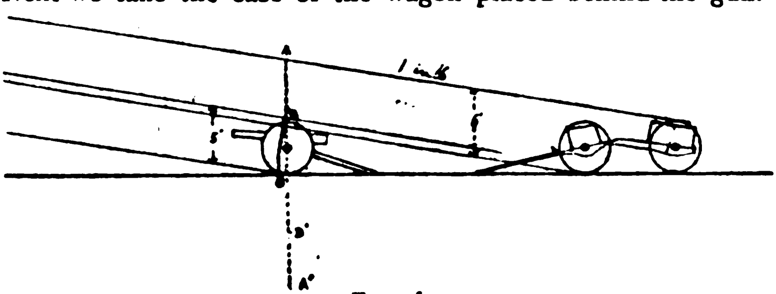


FIG. 16.

Fig. 16, which is drawn to scale, the wagon is shewn in the old regulation position with the point of the pole 3 yards from the trail eye. Take the mean point of impact at O; then by measurement OA= 10.25 feet, and AA' = 21.5 feet. The 50 °/₀ zone being 5.3 yards high, or 5.3 × 3 feet, the probability factor is $\frac{21.5}{5.3 \times 3}$ or 1.35, which, by the table, corresponds to 64°/₀. Of these 64°/₀, half will be grazes short and the other half, 32°/₀, will (if the line be correct) be hits upon the gun or wagon.

To find the percentage of hits upon the wagon alone, we must deduct the hits on the gun. BB' being 10 feet, the factor is $\frac{10}{5.3 \times 3}$ or .63, and the probable percentage 33°/₀, of which 16½°/₀ will be grazes short and 16½°/₀ hits on the gun. Therefore the hits on the wagon (subject to correction for line) will be 32°/₀ — 16½°/₀ or 15½°/₀.

But since a proportion of these shots, though correct for elevation, will be wide, we must multiply by the probable percentage of shots correct for line. The gun and wagon are each two yards wide and the lateral 50°/₀ zone 1.5 yards; the factor is $\frac{2}{1.5}$ or 1.33, and the probable percentage 63°/₀. Multiply by this and we have 10.4 °/₀ for the gun and 9.8 °/₀ for the wagon.

That is to say, that if 100 shots be fired at a gun and wagon, then, if the wagon be alongside the gun, the gun will receive 7.6 direct hits and the wagon 9.1 hits. But if the wagon be in the old regulation position behind the gun, then the gun will receive 10.4 hits and the wagon 9.8 hits.

The reason why the wagon receives fewer hits than the gun in the second case, although it offers a larger target than the gun, will be evident from the figure, which shows that with an angle of descent of 1 in 6 the gun masks a portion of the wagon. But it should be remembered that some of the hits on the gun will probably be effective on the wagon behind it.

Besides the reduced probability of being hit, the position of the wagon alongside the gun has other advantages, which will be discussed in Part III.

NOTE.—In the first edition of this book the slope of descent of the French shell was taken at 1 in 6 for 3000 yards. According to later information this is incorrect, and it is only at 4200 yards that the slope of descent increases to 1 in 6. The problem has been revised accordingly.

CHAPTER VI.

DEFLECTION OF PROJECTILES BY WIND.

This seems at first sight a simple matter to calculate. It would seem that we have only to calculate the lateral pressure of the wind on the shell, and thence the lateral velocity imparted to it. Unfortunately the results obtained by this method are very far from corresponding with those actually observed, the actual deflection being two or three times as great as the calculated deflection.

Greenhill's Method.

A more scientific method due to Sir George Greenhill, is given in the Text Book of Gunnery, 1907. The formula is

$$\text{Deflection in feet} = W\left(t - \frac{3R}{V}\right)$$

Where W is the velocity of the wind in feet per second across the range, *t* the time of flight in seconds, R the range in yards, and V the muzzle velocity in feet per second. All these figures can be taken from the range table.

Example.

A 15pr. Q.F. gun is fired at a target distant 3000 yards. The wind is blowing from the right front with a velocity of 30 f.s. How many feet to the left of the target will the shell strike?

The wind velocity across the range is 30 sin 45° = 21 f.s. From the range table at the end of this book,

$$\begin{aligned} t &= 7.93 \text{ seconds} \\ 3R &= 9000 \text{ feet} \\ V &= 1674 \text{ f.s.} \\ \text{Deflection} &= 21\left(7.93 - \frac{9000}{1674}\right) \\ &= 53.65 \text{ feet.} \end{aligned}$$

Captain Hardcastle's wind chart (which is here reprinted by permission) gives a good working approximation to the deflection required for a given force and direction of wind. It differs from other charts previously published in that it takes into account the fact that at the highest point of its trajectory the shell is exposed to a wind much stronger than that blowing on the ground level. Accordingly the scale of allowances is graduated for the known rate of increase of wind with altitude, as determined by meteorological experiments.

To use this chart, follow the circle marked with the speed of the wind till it cuts the "o'clock" of the wind. Read off vertically under the point so found the wind deflection in minutes on the scale marked with the range.

The words used to describe the strength of the wind are those used in the daily weather forecasts.

Examples of Use of Chart.

Range 3000, wind II o'clock, fresh.
Deflection 18 minutes right.

Range 4200, wind V o'clock, strong.
Deflection 22 minutes right.

Range 4500, wind VIII o'clock, moderate.
Deflection 24 minutes left.

CHAPTER VII.

RECOIL.

The question of recoil is of extreme importance to the design of a modern field-gun, and merits careful study.

Recoil Velocity.

When a gun is fired, the shell and the gun fly in opposite directions with velocities inversely proportional to their weights; that is, if we neglect the weight of the powder, which will be considered hereafter. If a shell weighing 10 lbs. be fired from a gun weighing 1000 lbs., then if the shell starts at 1000 feet per second the gun will recoil at 10 feet per second.

Let W be the weight of the gun, w of the shell: U the recoil velocity of the gun, v the velocity of the shell.

$$\text{Then } \frac{W}{w} = \frac{v}{U}$$

Recoil Energy.

The force of the powder is expended partly in propelling the shell forwards, partly in propelling the gun backwards. If the gun weighed no more than the shell, they would fly apart with equal velocities, and the work done upon each would be equal. If the weight of the gun were infinite, it would not move at all; the work done upon it (neglecting heating) would be nil, and the whole force of the powder would be expended on the shell. This is at first sight inconsistent with the truth that action and reaction are equal and opposite. This axiom however only means that the force exerted by the powder is equal in both directions. And since the work done by a force upon a body is proportional to the distance through which it acts, then the shell, which is acted upon for the whole length of the bore, must get more work done on it than the gun, which is only acted upon for the short distance through which it moves before the shell leaves the muzzle.

The work done upon a moving body, or the energy imparted to it (which amounts to the same thing) is expressed by the formula:

$$E = \frac{wv^2}{2g}$$

for the proof of which the student must refer to a treatise on Elementary Dynamics. Thus a 15 lb. shell travelling at 1640 fs. has stored up in it an energy of $\frac{15 \times 1640^2}{64.4} = 624{,}800$ foot pounds or $\frac{15 \times 1640^2}{64.4 \times 2240} = 279.7$ foot-tons.

Suppose this shell fired from a gun mounted on a rigid carriage, weighing altogether 1 ton; then the recoil velocity of the gun and carriage would be $\frac{15}{2240} \times 1640$ fs. $= 10.98$ fs. and the recoil energy of the gun and carriage would be $\frac{2240 \times 10.98^2}{64.4 \times 2240} = 1.873$ foot-tons.

This would be enough to lift the gun and carriage, if stopped from recoiling, 1.873 feet into the air.

Next suppose the same shell fired with the same velocity from a modern Q.F. gun. (This would require more powder, since in this case, as will be seen, more work is done on the gun and less in proportion on the shell). The weight of the recoiling parts, namely gun and buffer, would be about 800 lbs.; therefore the recoil velocity is now $\frac{15}{800} \times 1640 = 30.75$ fs., and the recoil energy $\frac{800 \times 30.75^2}{64.4 \times 2240}$ $= 5.365$ foot tons, or some three times as much as before.

How is it, then, that a Q.F. gun, which develops 3 times the recoil-energy of a B.L. gun, contrives to stand steady on firing? The answer is to be found in the arrangement of the buffer. As we know, a hydraulic buffer consists of a long cylinder filled with a viscous material such as glycerine or Rangoon oil. In this cylinder works a piston, which nearly fits it. The cylinder is attached to the gun, the piston-rod to the carriage. Then on recoil the cylinder moves backwards, drawing out the piston-rod; the oil or glycerine has to pass through the narrow space or windage between piston and cylinder, opposing a strong resistance as it does so. In a well-designed buffer the windage is so adjusted, by varying the depth of the ports in the walls of the cylinder, that the resistance opposed by the liquid bears a uniform ratio to the stability of the carriage throughout the recoil.

Now suppose that the gun and buffer recoil 4 feet before coming to a standstill. Then the recoil-energy of 5.365 tons has been expended in pulling out the piston 4 feet against a certain resistance. If we consider the resistance to be a weight, then we shall have expended 5.365 foot tons of energy in lifting that weight 4 feet; therefore the amount of the weight, or average resistance, must be $\frac{5.365}{4}$ $= 1.341$ tons.

Under the assumed conditions the effect of firing a Q.F. gun will be to produce a steady pull upon the carriage averaging 1.341 tons, acting through the line of motion of the centre of gravity of the recoiling parts. Since this force is greater than the weight of the gun and carriage, why does the carriage not overturn?

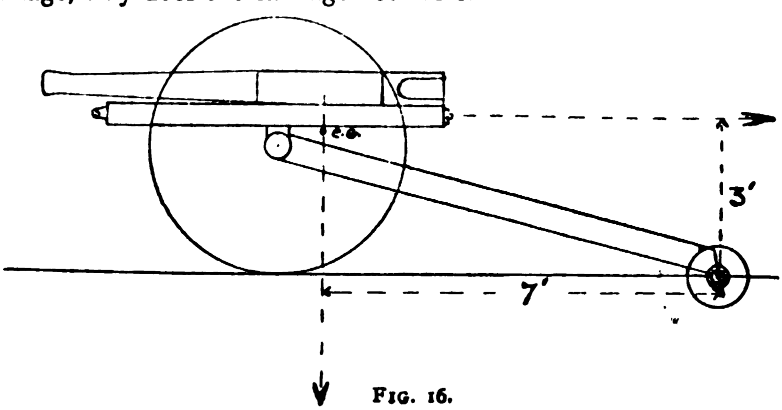


FIG. 16.

The reason will be apparent on considering the above figure. Suppose the carriage hinged to the ground at the point of the trail; then the pull of the piston-rod tends to revolve the carriage backwards about the fulcrum. The moment of the pull about the fulcrum is equal to its amount multiplied by the vertical distance of the C.G. of the recoiling parts from the fulcrum, which is about 3 feet. Similarly the weight of the gun-carriage, tending to keep the wheels on the ground, acts vertically downwards through the centre of gravity of the system, and its moment about the fulcrum is equal to the weight, about one ton, multiplied by the horizontal distance from the fulcrum, say 7 feet.

Then the overturning force of $1.341 \times 3 = 4.023$ tons is resisted by the downward force, $1 \times 7 = 7$ tons; therefore the wheels will not lift from the ground, and the carriage will remain steady.

Strictly speaking, the fulcrum should not be taken as the point of the trail, but rather as the centre of the area of the spade. In bad ground the fulcrum is still lower, since the spade then holds principally by its point.

Weight of Powder Charge.

In order to simplify the question, we have so far left out of account the weight of the powder-charge. This must however be reckoned with, as it adds materially to the recoil-energy.

In old text-books it was customary to consider the powder-charge as igniting from the middle, one half going forwards with the shell, and the other half backwards with the gun. In calculating recoil-velocities half the weight of the charge was added to the weight of the shell, the other half to the weight of the gun. This is however unsound, since the whole charge is propelled out of the gun before the latter has finished recoiling. And besides this, the explosion of the charge takes more effect upon the gun than it does upon the shell. For the forward impulse communicated to the latter by the expanding gases ceases when it has gone a yard or so from the muzzle, whereas the burning gases still continue to issue from the gun, producing a strong unbalanced pressure upon the breech, when the shell is already a hundred yards distant on its way. Accordingly Sebert's velocimeter (referred to in Chapter I.) shows that the maximum recoil-velocity is not attained till an appreciable time after the shell has left the muzzle.

We have then to modify our formula

$$\frac{W}{w} = \frac{U}{u}$$

and write $$\frac{W}{w + Cw'} = \frac{v}{U}$$

where w' is the weight of the charge, and C, known as the "muzzle blast factor," varies from 1 in long guns to 2 in short ones. For ordinary Q.F. field guns we may take C as 1.5. That is, instead of reckoning merely the weight of the shell we must add $1\frac{1}{2}$ times the weight of the charge of cordite or other smokeless powder.

As an example, we will calculate the recoil-velocity of the 15 pr. Q.F. gun by the amended formula.

Page 46.—With modern powder it is better to use a value of 2 for the blast factor in calculating the recoil of a 30-calibre field gun.

The shell weighs 14.3 lbs., the charge 1 lb. nearly; therefore $w + 1.5 \times w' = 15.8$ lbs. The gun and buffer weigh together about 850 pounds. The muzzle velocity with ballistite is 1640 fs.

$$\text{Then recoil-velocity} = \frac{15.8}{850} \times 1640 = 30.49 \text{ fs.}$$

$$\text{Recoil energy} = \frac{850 \times 30.49^2}{64.4 \times 2240}$$
$$= 5.479 \text{ foot-tons.}$$

Similarly, for the 18 pr. Q.F. gun,

$$W = 1175 \text{ lbs. (including half weight of springs)}$$
$$w = 18.5$$
$$w' = 1.44$$
$$\text{Recoil velocity} = \frac{18.5 + 1.44 \times 1.5}{1175} \times 1590$$
$$= 27.96 \text{ fs.}$$
$$\text{Recoil-energy} = \frac{1175 \times 27.96^2}{64.4 \times 2240}$$
$$= 6.368 \text{ foot-tons.}$$

Period of Recoil at which the Shell leaves the Muzzle.

This is an important point, influencing the accuracy of the shooting. Taking the 15 pr. Q.F. gun, the length of the rifling is $6\frac{1}{2}$ feet, and the average velocity of the shell up the bore is $\frac{1640}{2}$ or 820 fs.; therefore the shell takes $\frac{6.5}{820} = .007927$ seconds to reach the muzzle. The recoil-velocity when the shell leaves the muzzle is something less than 30.49 fs.; we may guess it at 29 fs. Then the average recoil-velocity up to the time the shell leaves the muzzle is half that or 14.5 fs. Then while the shell is travelling up the bore, the gun recoils $.007927 \times 14.5 = .1141$ feet or 1.37 inches.

Taking the 18 pr. Q.F. gun, the average velocity up the bore is $\frac{1590}{2}$ or 795 fs., therefore the shell takes $\frac{7.5}{795} = .00945$ seconds to reach the muzzle. Taking the recoil-velocity at 28 fs., the average recoil-velocity from rest is 14 fs. Therefore while the shell is travelling up the bore the gun recoils $.00945 \times 14 = .1323$ feet or 1.59 inches.

Therefore if we can so construct the buffer and carriage that the gun recoils smoothly for the first $1\frac{3}{4}$ inch, any subsequent jerk or vibration will not affect the shooting.

This is the real reason why the Q.F. guns shoot so much better than the old B.L. equipment.

STABILITY OF THE CARRIAGE.

We have so far assumed that the steadying moment, namely the weight of the gun and carriage multiplied by the distance of its centre of gravity from the spade, is constant throughout the recoil. This however is not the case, since the gun shifts some four feet to the rear during the recoil. We will now examine the question somewhat more closely. The following method of investigation is due to Sir George Greenhill.

Diagram of Steadiness.

Let the conditions be as follows—

Length of trail measured horizontally from centre of axletree to centre of spade	100 inches
Height of centre of gravity of recoiling parts above centre of spade	40 inches
Weight of gun and recoiling parts	10 cwt.
Weight of carriage on wheels	10 cwt.
Ditto on spade...	1 cwt.

Axis of gun, horizontal.

For simplicity, suppose that in the firing position, the centre of gravity of the gun and recoiling parts is exactly over the axle; then if the gun be shifted forward 10 inches it will balance the spade, and the whole weight, 21 cwt., will be balanced on the wheels. Then the distance from C.G. of gun and recoiling parts to spade will be 110″ horizontally.

Also suppose that the gun can be shifted back to a distance of 100 inches beyond the spade; then this will balance the weight on the wheels, and the whole weight will be on the spade. The distance between these two extreme positions of the gun will then be 210 inches.

We can now draw the diagram.

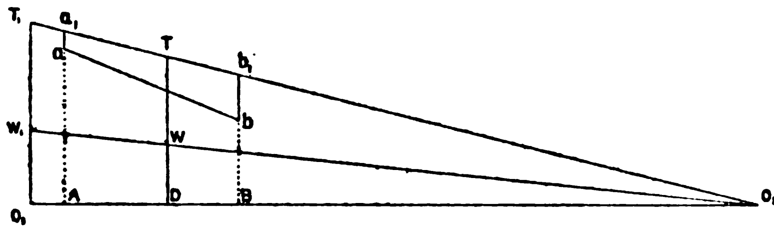


DIAGRAM OF STEADINESS.

Draw O_1O_2 representing 210″, and O_1W_1 upwards representing 21 cwt.

Then in the position O_1 the whole weight, 21 cwt., will be on the wheels; in the position O_2 the whole weight will be on the spade, and that on the wheels will be nil.

Join W_1O_2. Then at any point of recoil, if the C.G. of gun and recoiling parts be say at D, the weight on wheels will be DW.

Now on firing, the weight of gun and the weight on wheels. together 20 cwt., acts downwards at a distance from the centre of the spade of 100 inches, while the horizontal line in which the C.G, of the recoiling parts moves is 40 inches above the centre of the spade; therefore the weight which keeps the wheels down acts against the recoil which tends to lift the wheels at a mechanical advantage of 100 to 40.

Increase O_1W_1 to O_1T_1 in the ratio of 100 to 40, that is, make O_1T_1 represent $21 \times 100/40$ or 52.5 cwt., and join T_1O_2.

Then in any position of recoil D, TD represents the maximum pull on the carriage that will *not* lift the wheels from the ground.

Since the successive positions of T during recoil are all on the straight line T_1O_2, then, if the buffer-pull were the only resistance to recoil, the correct curve of buffer-resistance would be a portion of

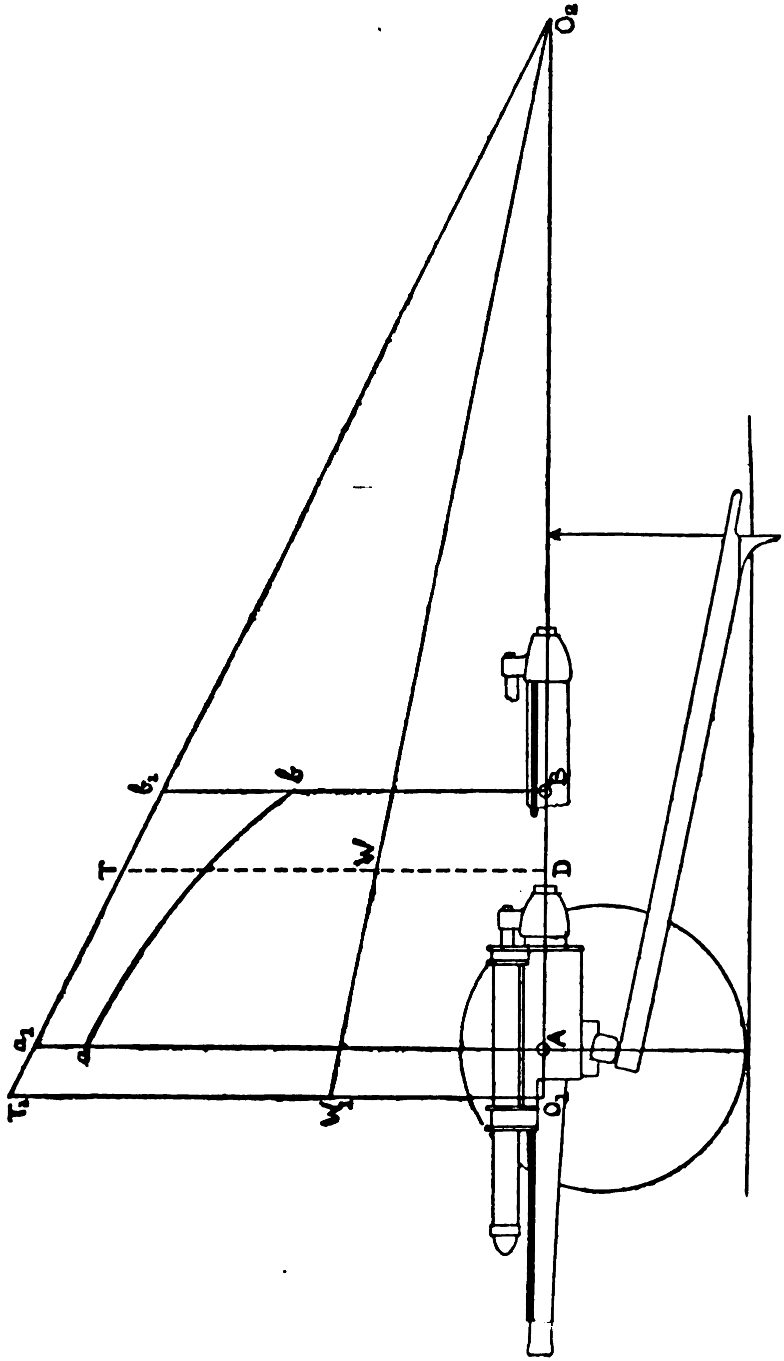


DIAGRAM OF STEADINESS.

the straight line T_1O_2. If the length of recoil allowed be 50 inches, from A to B, then the curve of buffer-resistance would be the straight line a_1b_1. But we have also to consider the compression of the springs. This must be sufficient, at any point of the run-up, to support the gun on a slope of about 1 in $2\frac{1}{2}$, besides about 1 cwt. of surplus compression to overcome the buffer-resistance. Therefore the initial compression of the springs must be at least 5 cwt. The maximum compression at full recoil depends upon the length of the recoil as compared to the length of the spring-column, and cannot be stated in general terms. Take it at 13 cwt. Since this spring-resistance must be deducted from the total resistance to get the correct buffer-resistance, draw b_1b downwards equal to 13 cwt, and a_1a downwards equal to 5 cwt. Then *ab* represents the correct theoretical buffer-resistance during recoil; that is, the resistance which just fails to make the wheels lift from the ground.

As a matter of fact *ab* is not a straight line, but a curve as shewn in the Plate, since the resistance of the spring does not increase in direct proportion to its linear compression, but in a higher ratio.

In getting out an experimental design, the draughtsman starts with the curve *ab*, and modifies it by allowing a reduced resistance at the start, in order to allow free recoil till the shell has left the bore. He then further modifies the curve to give a reduced resistance throughout the recoil, in order to allow a surplus of steadiness under unfavourable conditions, such as ground sloping to the rear. From this corrected curve, the graduated depth of the buffer-ports is worked out from empirical data, and corrected by the buffer-gauge described in Chapter I.

Attempts have been made to calculate the area of buffer-ports for different resistances. But the results are subject to so many corrections for the shape of the apertures, and of the spaces through which the liquid obtains access to them and emerges from them, as to be of little practical value.

In order to bring the gun to a standstill, the length of AB of recoil must be such that the area of the curve *ab* above the line AB, representing the total resistance to recoil, is equal to the area, drawn to the same scale, representing the total recoil-energy. Therefore if the draughtsman starts with the area A *ab* B, exactly equivalent to the recoil-energy, then, when he has cut down the curve, he must increase AB, the length of recoil, in order to maintain the same area, representing the total resistance to recoil. This is shown in the following figure.

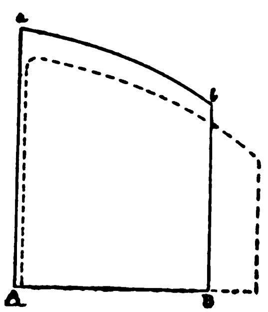


FIG. 18.

It must be remembered that if at any point of the recoil the wheels begin to lift, this at once increases the height of the centre of gravity of the recoiling parts above the point of the trail, and so increases the overturning moment. The lifting will then continue until the energy expended in raising the weight of the gun and carriage is equal to the surplus recoil- energy unbalanced by the buffer-resistance. Thus the total recoil-energy of a field gun weighing one ton is about 5 foot-tons; if only $\frac{4}{5}$ of this be absorbed by the buffer and springs and by the compression of the earth behind the spade, the weight of the gun and carriage will be raised 1 foot when the gun is fired, which means that the wheels will be lifted more than one foot from the ground.

Running-Up Pressure.

During running-up the springs exert a backward pressure on the rear plate of the cradle, tending to press the spade into the ground, and a forward pressure on the buffer-cylinder. The latter is communicated through the buffer-piston to the front of the cradle and so to the carriage, and tends to lift the spade out of the ground. So long as the gun and buffer continue to give way to this latter pressure, and to move forward, the parts are not in a condition of static equilibrium, so that it is less than the pressure on the base-plate of the cradle, and there is no tendency to shift the carriage forward or to lift the spade. But if the buffer-resistance is insufficient to bring the gun to rest in the firing position, the gun runs up against the stops at the front of the cradle, producing a dynamic jerk which may be sufficient to lift the spade. If the gun when it strikes the stops has still a forward velocity of 5fs., then if (as assumed) the weight of the gun and recoiling parts is 10 cwt. as against 11 cwt. for the lower carriage, then the effect of the impact will be to impart a momentary velocity of nearly 5 fs. to the carriage till again checked by the springs; while the gun rebounds from the stops and comes to rest. If the carriage be prevented from moving forward by the wheel-brakes, then it will tend to overturn forwards, lifting the spade out of the ground.

It is therefore necessary that the buffer-resistance to running-up should be sufficient to absorb all (or nearly all) of the work done by the springs.

In the figure the work of the buffer-resistance is denoted by the area $ABab$, and the work done by the springs by the are aba_1b_1. It will be seen that in the case of a gun the latter is much less than the former. But in the case of a howitzer, powerful springs have to be used to lift it at 45° elevation, and it may be necessary to increase the buffer-resistance in running up at low angles of elevation, as by the use of the Vavasseur gear, to prevent the carriage from overturning.

We have so far considered the gun in the horizontal position only. When the gun is fired with any elevation, the distance of the line of motion of the recoiling parts from the fulcrum (Fig. 17) is less, and so the overturning moment is reduced. Therefore if the gun is steady point-blank it will be steady at any angle of elevation.

On the other hand, if the gun is fired with depression it will require a surplus of stability to keep the wheels from lifting.

Similarly, if the gun be fired from a reverse slope without elevation, or if the slope be steeper than the angle of elevation, the point of the trail will be lower, the overturning moment will be greater, and there will be a tendency to unsteadiness.

ADJUSTMENT OF STABILITY.

Suppose that it is required to design a stable carriage for a gun of given muzzle energy.

Then the first condition to be satisfied is that the total resistance to recoil must be equal to the recoil energy; if it be less, the gun will recoil off its carriage. Thus if the recoil-energy be five foot-tons, we must have (neglecting the springs) a buffer 5 feet long with an average resistance of 1 ton, or 2½ feet long with a resistance of 2 tons, or in like proportion. Now the recoil-energy itself may be modified by the design; since the recoil velocity is inversely proportional to the weight of the recoiling parts, or nearly so,* we may reduce it by increasing the weight of the gun. This is a most unscientific method, since the horses will have to pull a quantity of dead weight which might be saved by a proper design of the carriage. Therefore in a well-designed field equipment the weight of the gun should be as low as it can be brought without danger of bursting. This fixes the recoil-energy.

The weight of the carriage must also be the minimum required to carry the gun and to stand the recoil without breaking. But as regards the latter point, the stress on the carriage on firing is proportional to the buffer-resistance which is transmitted to it by the cradle, so that if we reduce the maximum (not the total) resistance we may be able to lighten the carriage.

Now there is only one available way of reducing either the maximum or the average buffer-resistance, while still keeping the same total. This is to lengthen the buffer, and to allow a longer recoil. After a certain point, however, the increased weight of the buffer, springs, cradle, and guides sets a limit to the application of this method; moreover if the recoil be too long, the gun will strike the trail or the ground when fired at high elevations.

Suppose that we have increased the length of recoil till nothing further is gained thereby, and that the carriage is still unstable, we can still increase the mechanical advantage of the steadying weight over the overturning force. If we increase the length of the trail we increase the leverage of the steadying weight. Here, however, there is a limit, since the trail, if made longer, has also to be made stouter and heavier in order to stand the same amount of thrust on firing. Finally, we may reduce the height of the axis of the gun—or rather of the centre of gravity of the recoiling parts. In our own service this is effected by putting the buffer on top of the gun, so as to get the gun, which is much heavier than the buffer, right down on the axletree. In the Russian gun the same object is effected by cranking

*Not exactly so, since a reduction in recoil velocity means a slight increase in muzzle velocity, and so alters the terms of the recoil equation.

the axletree downwards in the centre. This however increases the weight of the axletree and reduces the clearance under the gun, which is undesirable when rough ground has to be traversed. In the French equipment, the wheels have been reduced to 4' [illegible] in diameter, with the same object in view; but we in England consider these wheels too small for mobility. The lowest gun of all is the Japanese semi-quick-firer used in the Manchurian War, which has the trunnions of the gun extended so as to form the axletree arms. 4' 6''

In a well-designed equipment the above features are combined so as to get a stable gun of maximum power and minimum weight.

Two other methods of obtaining increased stability, namely differential recoil and curved recoil, will be considered in Chapter XV.

Part II.

PRINCIPLES OF CONSTRUCTION
OF
GUNS, CARRIAGES, AND AMMUNITION.

CHAPTER VIII.

ORDNANCE MATERIALS.

STEEL.

Steel is the only material now used in gun-making.* There are many different kinds of steel, ranging from *high* steel (that is, containing a high percentage of carbon) of which razors are made, down to the mild steel used for boiler-plates. High steel is harder, stronger, and more elastic than mild steel, but it is also more brittle. When steel guns were first made only the softest and toughest of mild steel was used, principally because it was then impossible to obtain large ingots of high steel of good quality. With improvements in steel we are now getting to use much higher steel than before. A few years ago the steel used at Woolwich was specified as 30 tons tenacity; that is, that a bar of steel an inch square would stand a pull of 30 tons before breaking. At present there is no difficulty in obtaining 60-ton steel.

Hardening. Both high and low steel are improved by hardening and tempering. Hardening consists in heating to a red heat and quenching in oil or water; tempering consists in re-heating to modify the effect of the hardening. Mild steel does not harden to anything like the same extent as high steel, but it gains in strength and elasticity thereby.

Natures of Steel.

Steels of different quality are used for making guns, carriages, gun-springs, shells, and shields.

Gun-steels are usually low in carbon, and may be classed as mild steels rather than high steels. The steel used for heavy guns has usually a tenacity of from 40 to 45 tons per square inch, untreated, while steel with tenacity up to 60 tons is used for field guns.

Carriage steel is still milder than gun steel, as it is required to be tough rather than elastic. Two qualities are generally used, namely 30-ton steel for trails and fittings, and 50-ton steel, with a high elastic limit, for axletrees.

Spring steel, besides high elasticity, has to possess great power of withstanding fatigue due to repeated sudden flexion. It is considered that one pound of spring should be capable of repeatedly absorbing and giving out 40 foot-pounds of work.

Shell steel comprises cast steel for thick-walled armour-piercing shell, and forged steel for shrapnel. The former has to be exceedingly hard, otherwise it sets up on impact instead of penetrating. Shrapnel steel requires to be tough as well as hard, since the walls of the shell are thin, and there is a risk of breaking up as well as of setting up in the bore. A breaking strain of 55 to 60 tons per square inch, with elongation of 8 to 10 per cent, is generally considered suitable.

*Except in Austria, where, for reasons connected with economy and local facilities of manufacture, forged bronze is still used. This, however, involves a material increase of weight.

Page 57.—In 1912 the Austrians decided to abandon the use of bronze for all guns to be built in future.

Steel for gun-shields is used in plates 1/8" to 1/4" thick. It is required to resist penetration by rifle bullets at short ranges. It has to be exceedingly hard, and must be tough enough not to break when struck. The breaking strain is usually about 100 tons per square inch.

Composition of Steel.

Carbon is necessary to obtain sufficient hardness and tenacity. But the modern tendency is to use the minimum of carbon necessary to produce the required tenacity, in order to make the metal as tough as possible. Thus nickel steel with only 0.3 per cent of carbon is now used where formerly ordinary steel with 0.5 per cent of carbon would have been employed.

Nickel considerably increases the strength and elasticity of steel. English makers use about 3 per cent, German makers as much as 6 per cent. It is frequently used in combination with chromium and tungsten.

Chromium up to one-half per cent increases the strength and hardness of the steel. Up to 1.5 per cent is used for armour plates. Chrome gun-steel must be comparatively free from manganese, otherwise it cracks when treated. It is improved by the addition of a small percentage of molybdenum.

Tungsten or *Wolfram* increases the hardness and density of steel, and is used for gun-shields in proportions not exceeding one-half per cent. High-speed tool steel contains up to 25 per cent of tungsten. If the proportion be as much as 16 per cent, the steel is nearly as heavy as lead, and is suitable for shrapnel bullets intended to pierce gun-shields. The quantity of tungsten commercially available is however to small to allow of its use on an extended scale.

Vanadium increases the strength and elasticity of steel. From 0.1 to 0.2 per cent is used, ordinarily in conjunction with chromium up to 1 per cent. Vanadium steel has not been tried for guns.

Molybdenum is said to make good spring steel if used in proportions up to 0.1 per cent.

Manganese is present in most gun-steels. In ordinary gun steel as much as 1 per cent may be present without doing any harm, but the proportion should not exceed 0.4 per cent for chrome steel or 0.1 per cent for tungsten steel.

Copper is present in a few steels, such as some of Krupp's steels, in proportions up to 0.12 per cent. It is supposed to contribute to toughness.

Silicon makes good fluid steel for castings, which may contain as much as 1 per cent; but for forgings the percentage does not usually exceed 0.5. Up to 3 per cent silicon is used for spring steel.

Sulphur, phosphorus and arsenic are deleterious and are eliminated as far as possible. *Aluminium* is sometimes used in casting, to produce fluid metal. It is supposed to rise to the top of the dead-head with the impurities. Its use except in minute quantities is forbidden by most Governments, as if any remains in the steel it makes rotten spots.

Steel Tests.

These are of two kinds, namely static and dynamic tests. In the former the steel is slowly stretched or compressed; in the latter it is subjected to a sudden blow. It must be clearly understood that the results obtained in a static testing machine are not directly applicable to steel stressed by a force suddenly applied, as when a gun is fired. Thus the A tube of a gun is frequently found to stretch, although subjected to a stress well below its static elastic limit. No serious attempt has yet been made to reproduce firing conditions in a testing machine, although this would not seem to be impossible. The gun-maker is guided principally by the static tests, the relation between the static results and those obtained in the gun being determined by experience with the steel in question.

The meaning of the terms used in static testing may be illustrated as follows:

Suppose a bar of steel 100 inches long and 1 square inch in cross section stretched in a testing machine. Then if a pull of 50 tons were required to break it, its tenacity would be 50 tons per square inch, and it would be referred to as 50-ton steel. Suppose its length just before breaking were 120 inches, it would have an elongation of 20 per cent. Suppose that at tensions up to 30 tons the bar returned to its original length when released, and that over 30 tons it began to yield, or stretch permanently, its elastic limit, or yield point, would be 30 tons per square inch.

Static tests are usually taken on a piece of steel turned to ½″ in diameter and 2″ long between shoulders. It is not likely that tests taken on such a piece would be found to apply to a bar 100 inches long, unless the metal were of exceptionally uniform quality.

German gun-makers use a self-registering hydraulic testing machine, in which the tension applied and the extension of the test piece are recorded on a drum. The drum is connected to the moveable jaw holding the test piece so that it revolves as the piece stretches, at the rate of 100 millimetres for every millimetre of extension. The indicator which traces the curve on the drum is connected by a pipe to the cylinder of the hydraulic ram, so that it rises as the force applied increases. The yield point, at which the piece begins to stretch permanently, is shown by a break in the curve.

Various dynamic testing machines are used. The simplest is the pendulum machine. The bar of steel to be tested is notched to a given section, and set vertically in a vice. A heavy pendulum is arranged so as to strike the bar in its swing. The energy of the blow is determined by the height to which the pendulum is raised before it is released, and the energy remaining in the pendulum is measured by the height to which it swings after breaking the bar.

The following extract is taken from a most valuable article by Colonel Holden, R.A., to which students are referred for further information.*

* Times Engineering Supplement, March 3 and March 10, 1909.

Page 59.—The Charpy dynamic testing machine has a heavy pendulum into which the test piece is fixed tangentially. A cross piece fixed on the end of the test piece is arrested as the pendulum swings through a gate, so that the piece is broken by shock tension.

TREATMENT AND TESTS.

Whilst wrought iron, which is the nearest commercial approach to pure iron, can be very roughly used, so far as heating, forging, and cooling are concerned, without affecting its character after such treatment such is not the case with steel containing anything over 0.3 or even 0.25 per cent. of carbon. There is no doubt that the introduction of steel for general purposes was kept back for years owing to the want of appreciation of this fact. The alloy steels, however, are many times more sensitive to ill-treatment, and some of them are so delicate in this respect, that it is often a wise policy on the part of the manufacturer not to attempt to treat the parts he has machined, but to leave this to the steel-maker, who should thoroughly understand not only how to treat but also the why and wherefore of the treatment of his own steel. The testing of steel is a much more complicated matter than it was a few years ago, when users were content with a tensile test and perhaps a bending test, the former being carried out very frequently with a bar some five inches in length, turned down for some 2.5 inches to a diameter corresponding to a sectional area of .25 square inch, and marked with points two inches apart for the purpose of ascertaining the yield point, elastic limit, and percentage of elongation. This test piece is then held in the jaws of a testing machine, in which the stress can be gradually increased until the specimen breaks, the yield point and elastic limit being observed during the process. and the elongation being generally measured afterwards. Apart from the figures thus obtained, the appearance of the fracture is of a considerable value in indicating whether the steel is in good or bad condition. The bending test consists in bending a rectangular bar of the material to be tested around a cylindrical former, having a definite diameter as compared to the piece under test. A good piece of material should be capable of being bent into U form, that is, through an angle of 180 degrees, not only without breaking, but without showing any sign of cracking on its exterior surface.

Modern science, however, demands more information than can be gathered directly from such tests as these. It is necessary to know how a steel will behave under shock, under continuous as well as intermittent stress in one direction, and under stresses alternating in direction; what its intrinsic hardness is, and also the molecular condition of the material as shown by the microscope. The "shock" test, as it is called, is generally applied to a rectangular bar, which has a V-shaped notch cut across it to give it a determined line of weakness, by dropping a weight from a certain height upon the unsupported end and measuring the amount of energy remaining in the weight after the bar has been broken. The energy absorbed in breaking the bar can thus be deduced. The stress tests are made in machines which apply a load, in the manner required, either continuously, intermittently, or alternately in either direction, until the test piece fails by cracking or breaking, or shows signs of fatigue.

The test almost universally applied for hardness is made in the following manner. A steel ball such as is used for ball-bearings, 10 millimetres in diameter, is placed on the surface of the material to be tested, and is subjected to a definite pressure for a few seconds. The diameter of the crater thus produced in the material under test is measured, and is a function of the hardness of the material.

Erosion.

When a gun is fired, the temperature in the bore is considerably higher than the melting point of steel. The layer of the metal next to the powder is heated red hot and is scored and channelled by the rush of the gases. This erosion does not occur to any serious extent in field guns, but materially shortens the life of a heavy gun. Experiments have been carried out to determine the relative resistance of different natures of steel to erosion. An explosion vessel was fitted with a perforated plug through which the powder gases had to escape, and the plug was weighed before and after each explosion. Plugs of various natures of steel were used. Contrary to expectation, it was found that high-speed tungsten tool steel was eroded much more than ordinary steel. Nickel gun-steel did fairly well, but simple mild carbon steel suffered least of all. It is claimed for vanadium steel and molybdenum steel that these resist erosion well, but the assertion has not yet been put to any practical test. Generally speaking, it has been found that any alloy erodes more than a pure metal.

Bronzes.

In addition to steel, various bronzes are used in the construction of gun-carriages. Manganese bronze is used for castings of complicated shape, such as the 18pr. cradle. Phosphor bronze is hard and close-grained, and is use for pipe-boxes. The composition and tests of these bronzes are given in the table at the end of this book.

The specification of the forged bronze used for the Austrian field gun is as follows :

A tube, elastic limit 19.27 tons, tenacity 36.39 tons
Jacket, „ „ 15.5 „ „ 27.5 „

TABLE OF GUN STEELS.

Unless otherwise stated, these figures refer to untreated steel, neither hardened nor tempered. The tests were taken on test pieces cut from large forgings under the conditions approved by the English and foreign Governments, except in the case of the Schneider tests, which are taken on test pieces 4" between shoulders, cut across the forging, which is a severe test. Fancy results may be obtained from small experimental forgings, but these are unreliable.

		Yield tons per square inch.	Break tons per square inch.	Stretch %
1.	Simple open-hearth steel, Messrs. Firth, Sheffield. Carbon 0.48, Mn. 0.87, Sil 0.17, Phos 0.028, Sul. 0.035 per cent	28	48	12
2.	Ehrhardt nickel gun steel, oil tempered. Nickel 6.0, Tungsten 0.5, Carbon 0.26, Sil 0.5, Mn. 0.25, Sul. 0.02, Phos. 0.02	39	67	19
3.	Armstrong nickel gun steel, treated	40	49.4	24.5
4.	Firth's ditto	35	54	20
5.	German ditto, 5% nickel	33.7	50.4	21.5

TABLE OF GUN STEELS—*Continued.*

		Yield tons per square inch.	Break tons per square inch.	Stretch %
6.	Bethlehem, U.S.A., nickel gun steel, treated. Nickel 3.33, Carbon 0.36, Mn. 0.81, Sil. 0.032, Phos. 0.026, Sul. 0.034	—	60	16
7.	Schneider, Creusôt, nickel gun steel for 12" A tubes, untreated. Nickel 2, Carbon 0.4, Mn. 0.06, Sil. 0.2, Phos. 0.025, Sul. 0.025	28.5	44	19
8.	Krupp's nickel gun steel for 11" A tubes, untreated	25	45	15
9.	Hadfield's special gun steel, oil-tempered ..	49.5	60	23.5
10.	Armstrong nickel-chrome gun steel, treated ..	59	63.5	18.5
11.	Schneider chrome steel for field guns, untreated. Carbon 0.3, Chromium 0.5, Mn., Sil., &c., as above..	24	38	22
12.	Armstrong ditto, treated	65	87.4	12.5
13.	Firth's nickel-chrome axletree steel, untreated ..	43	55	25
14.	Ditto, oil-tempered	51	62	22
15.	Ehrhardt's nickel steel for axletrees, untreated ..	47.7	50.4	23
16.	Krupp's spring steel, tempered	89	137	—
17.	Ehrhardt's ditto	120	142	3
18.	Cammell Laird's ditto, said to contain molybdenum	107	123	2
19.	Ehrhardt nickel-tungsten shield steel, untreated ..	80	105	5.5
20.	Bethlehem ditto. Carbon 0.29, Tungsten 3, Mn. 0.09, Sil. 0.035, Phos. 0.012, Sul. 0.05	—	—	—
21.	Schneider steel for shrapnel bodies, water-hardened and tempered	47	63.5	8.5
22.	Schneider nickel-chrome steel for armour plates, untreated. Carbon, 0.5, Nickel 2.5, Chromium 1.0, Mn, 0.06, Sil. 0.2, Phos. 0.025, Sul. 0.025 ..	—	—	—

CHAPTER IX.

PRINCIPLES OF CONSTRUCTION OF GUNS.

In designing a gun to fulfil a given task, we have first to determine its interior dimensions, then the material, the exterior dimensions, and the method of construction.

The interior dimensions are arrived at by knowing how much useful work is produced when a given weight of powder is ignited and expanded to a given volume. This is tabulated for cordite M.D. on page 126 of the 1907 Text Book of Gunnery.*

As an example, we will supposed that it is desired to produce a field gun to fire a 20 lb. shrapnel with M.V. of 2000 fs. We have first to determine the calibre. Since the 18 pr. has a calibre of 3.3 ins., we may try 3.5 ins. for our gun. The powder being cordite M.D., we will try a charge of 2 lbs. By comparison with the 18 pr., this will require a chamber of 135 cubic inches. Now the amount of useful work we require from the powder is $\frac{20}{2240} \times \frac{2000^2}{2g}$ or 625 foot-tons. As explained in Chapter I, the useful work is calculated by deducting the work done by the powder in expanding to the volume of the chamber, 135 cubic inches, from that done in expanding to the volume of the whole of the bore, including the chamber. Try a 3.5″ gun of which the shot-travel (not the whole gun) is 40 calibres.† Then the volume of the bore without the chamber will be $\frac{1}{4}\pi d^2 \times l = .7854 \times (3.5)^2 \times 40 \times 3.5$ or 1340 cubic inches, and that of the bore and chamber 1475 cubic inches. Then, using the formula on page 127 of the Text Book of Gunnery:

$$V_0 = \frac{135}{27.7 \times 2} = 2.44$$

$$V_1 = \frac{1475}{27.7 \times 2} = 26.6$$

$$E(V_0) = 219 \qquad E(V_1) = 641$$

Multiply the difference by the weight of the charge, and we have

$$(641 - 219) \times 2 = 844 \text{ foot-tons.}$$

*This table may be used for cordite M.D.T. if allowance be made for the increased efficiency of this powder, which gives about 5 foot-tons per pound more than cordite M.D. It is not suitable for cordite.

† Note.—Generally speaking, a gun is measured by its total external length in calibres. Thus a 30-calibre 3-inch gun is 90 inches long over all. The bore is measured from the face of the breech block to the muzzle. In internal ballistics guns are compared with reference to the number of calibres which the shot travels, and the shot-travel, that is the distance from the front of the powder chamber to the muzzle, is sometimes referred to as the bore.

We have next to multiply by the factor f. Now the efficiency of the charge, as calculated from the foregoing table, is subject to certain deductions. Besides imparting the forwatd velocity to the shell, the powder has to impart the velocity of rotation, and to overcome the resistance of the driving band and the friction in the bore. Also, as shown in Chapter VII, part of the energy is expended in causing the gun to recoil. In a gun of which the shot-travel is 25 calibres, it is found that only about six-tenths of the energy given in the table is realized in the shape of muzzle energy. In the present gun, the waste is less, for the following reason: A large part of the wasted energy is expended in forcing the driving band into the rifling, which takes some 6 or 7 tons of pressure per square inch. This waste is the same whatever the length of the gun, and hence bears a larger proportion to the whole energy developed in a short gun than in a long one. By comparing our gun with others of approximately similar proportions, we may estimate that we shall realize rather more than seven-tenths of the energy as determined from the table.‡

We therefore take factor f as 0.725. Then

$$844 \times .725 = 612 \text{ foot-tons.}$$

which is 13 foot-tons short cf the muzzle energy which we require. Try the effect of increasing the calibre to 3.75 inches, while keeping the same length. This gives us slightly too much; try 3.65. Then the chamber capacity remains the same, while that of the bore is

$$1340 \times \left(\frac{3.65}{3.5}\right)^2 = 1460 \text{ cubic inches.}$$

and that of the bore and chamber 1460 + 135 or 1595 cubic inches.

$$\text{Then} \quad V_1 = 28.75 \qquad E(V_1) = 651.25 \qquad E(V_0) = 219.$$

$$\text{difference} = 432.25$$

Then total work will be 2×432.25 or 864.5 foot-tons, and work effective on shell $864.5 \times .725 = 626$ foot-tons, which is 1 foot-ton more than is required.

Since we have increased the calibre of the gun without increasing its length, the shot-travel will now be somewhat less than 40 calibres, namely $40 \times \frac{3.5}{3.65}$ or $38\frac{1}{4}$ calibres, and the total length of the gun will be about $44\frac{1}{4}$ calibres or 13.5 feet.

The same muzzle velocity might be obtained with a shorter gun if more powder were used; but this would mean higher pressures in the bore and a thicker and heavier gun.

The next step in the design of the gun is to calculate the pressures at various points of the chamber and bore, in order to determine the proper thickness of the metal at each point. Unfortunately this is not a mere matter of arithmetic. The rate of burning of the cordite, and the consequent pressure developed at various points, follows a somewhat obscure law. We know, however, that fine cordite gives

‡ NOTE.—In the actual design of guns at Woolwich the table on page 126 of the Text Book of Gunnery is not used. The Woolwich authorities use an empirical curve plotted from the results of many thousands of rounds fired from different guns, which gives a very close approximation to the actual muzzle energy which will be developed by a given charge in a given gun.

high pressures at the breech and lower ones at the muzzle. while coarser cordite gives more uniform pressures up the bore. If it be desired to get the gun as light as possible, the maximum pressure should be as low as possible; hence it is in this respect desirable to use the coarsest size of cordite that will be completely consumed before the shell leaves the muzzle, allowing a certain latitude for the different behaviour of cordite at different temperatures. In a gun with the shot-travel 40 calibres long the size of the cordite should be such that it is all consumed by the time the shell has travelled about 30 calibres.

But the calculation of the correct size of cordite is a complicated matter, involving problems which cannot be dealt with in an elementary work such as the present one. Practical experience enters largely into the matter.

A combination of several methods is used in gun-designing. The gun fitted with cutter-plugs described in Chapter I, used in conjunction with the chronoscope, has given valuable results, but the expense of constructing such a gun for every calibre in the service would be prohibitive. More generally-applicable results are obtained from the explosion vessel described on page 4. Broadly speaking, however, the methods of calculating powder-pressures now at the disposal of gun-constructors only give the results to be expected when known conditions are modified to a moderate extent. For instance, if Krupp and Armstrong were each called upon to design a 15-inch gun firing an entirely new propellant, the two designs would probably differ considerably, and it would be difficult to predict which would prove the better of the two.

We will suppose that the charge and size of cordite is so adjusted as to give a pressure of 12 tons at the point of maximum pressure, decreasing in a curve similar to that in Fig. 2 to 3 tons at the muzzle. The next thing is to determine the thickness of metal required to resist this pressure at each point.

Take, for example, a point at which the pressure is 10 tons per square inch, and consider a transverse slice of the gun 1 inch thick.

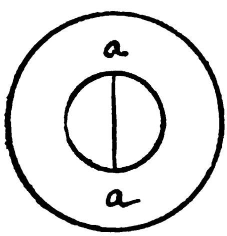


FIG. 19.

Imagine the gun divided by a vertical partition as in the figure, and consider either side of the gun. The inward pressure on the partition (the diameter being 3.75 inches)* will be 3.75 × 10 tons, and the outward pressure, tending to tear the metal apart at *a a* and

*Ordinarily speaking, the calibre (in this gun 3.65 ins.) is measured between the lands. But in calculations dealing with the strength of the gun, the greatest diameter of the bore, that is, the calibre to the bottom of the grooves, has to be taken. Since the grooves will be .05 inch deep, this makes the full diameter of the bore 3.75 inches.

so burst the gun, will be equal and opposite to the inward pressure. Therefore the two sections of metal at *a a* will between them have to stand a pull of 37.5 tons. Taking a factor of safety of 2, they will have to be strong enough to stand a pull of 75 tons together, or 37.5 tons each.

It would, therefore, at first sight appear that if we use, say, 50-ton steel, we have only to make the metal $37.5 \div 50$ or 0.75 inch thick. This however is not the case. It would be so if the gun were made of absolutely rigid inelastic material. But since no such substance exists in Nature, we have to use an elastic material such as gun steel, which is more perfectly elastic than india-rubber, although its limits of extension are not so great. Now it requires no mathematics to shew that if an elastic ring be expanded by pressure from the inside the stress on the inner layers, next to the pressure, is greater than that on the outer or more distant ones. The subject is treated mathematically in the Text Book of Gunnery, 1907. It was shewn by the late Mr. Peter Barlow that the stress on the metal is not uniform throughout, but varies inversely as the square of the distance from the centre, that is, from the axis of the gun. This formula, known as "Barlow's Law," is not quite accurate, but can be made so by using a modifying factor which is a constant for any particular size of gun. This is equivalent to sliding the curve sideways. For our present purpose "Barlow's Law" is near enough to the truth. But in actual gun-designing the modifying factor is too important to be neglected.†

In this case the ~~external~~ inner radius of the gun to the bottom of the grooves is 1.875 inches, and the outer radius, if the metal were 0.75 inches thick, would be 2.625 inches. So that if the outer layers be stressed to the breaking point, namely 50 tons per square inch, the stress on the inner layer, at the surface of the bore, would be $\left(\frac{2.625}{1.875}\right)^2 \times 50 = 97.5$ tons per square inch, so that the gun would certainly burst when fired.

Moreover we must remember that though our gun steel will stand 50 tons to the square inch before breaking, it will begin to stretch permanently at about 25 tons. For although the static elastic limit for 50 ton steel is over 30 tons, the dynamic yield point, which is what we must consider in gun construction, is consideraby lower (see Gun Steels.) We have therefore to solve the following problem:

Assuming for the sake of safety that our gun has to stand double the normal calculated powder-pressure, we have to construct it so that the resulting stress on the metal does not exceed 25 tons per square inch at any point.

(This is considerably in excess of the limits allowed in our service. See Text Book of Gunnery, 1907, page 155. In this case we have

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† Mathematically, the equation to the Barlow curve is :—

$$p = \frac{a}{r^2} - b$$

where *a* is a constant depending on the strength of the metal, and *b* is arrived at by experience. The constant *b* (which may be positive or negative in value) is always much smaller than *a*. In the present chapter we have simplified matters by omitting *b* altogether.

assumed that 50-ton steel of very high quality, with an exceptionally high yield point, is used.)

This problem may be solved in several different ways. We will first suppose that the gun is to be made of a single block of steel, and we will calculate the thickness of the metal at a point where the normal calculated powder-pressure is 10 tons per square inch. For the sake of safety we have to assume that a pressure of double this amount may possibly occur. This, as has been shown above, means that the metal on each side of the bore will be subjected to a pull of 37.5 tons. We have then to make the gun so thick that the metal at the surface of the bore, where the stress is greatest, is not stressed beyond 25 tons to the square inch.

Take a piece of squared paper, and draw a circle 3.75″ in diameter for the bore; draw a horizontal diameter, and at one end of it erect a perpendicular 25″ high (or to any suitable scale) representing the stress per square inch on the inner layer of the metal. Then, since the stress is inversely proportional to the square of the distance from the centre, at a point 2 inches from the centre it will be $\left(\frac{1.875}{2}\right)^2 \times 25$ or 21.97 tons, at $2\frac{1}{2}$ inches from the centre it will be $\left(\frac{1.875}{2.5}\right)^2 \times 25$ or 14.06 tons, at $2\frac{3}{4}$ inches 11.62 tons, and so on. Erect perpendiculars of these heights at these distances from the centre, and draw a curve through their tops. This gives the curve shewn in Figure 20, known as the "Barlow Curve." If perpendiculars be drawn up to this curve, say $\frac{1}{10}$ inch apart, and measured, these

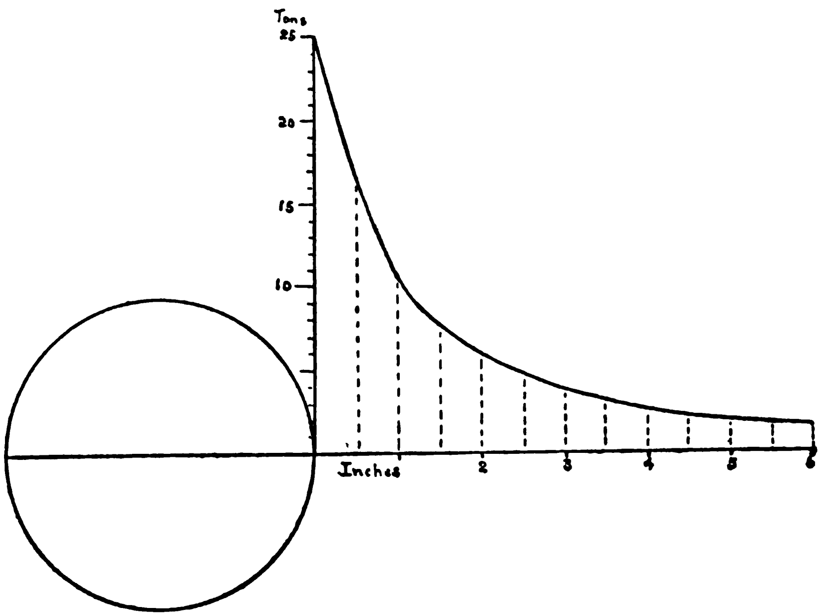


FIG. 20.

THE "BARLOW CURVE."

TABLE A.

2.50	
2.25	
2.04	
1.86	
1.70	
1.56	
1.43	
1.33	
1.23	
1.14	17.04
1.06	
0.99	
0.93	
0.87	
0.82	
0.77	
0.73	
0.69	
0.65	
0.62	8.13
0.59	
0.56	
0.53	
0.50	
0.48	
0.46	
0.44	
0.42	
0.40	
0.38	4.76
0.37	
0.36	
0.34	
0.33	
0.32	
0.30	
0.29	
0.28	
0.27	
0.26	3.12
0.25	
0.24	
0.23	
0.23	
0.22	
0.21	
0.21	
0.20	
0.19	
0.19	2.17
0.18	
0.18	
0.18	
0.17	
0.17	
0.17	
0.16	
0.16	
0.16	
0.15	1.68
Total	36.90

will give the stress on each successive layer of metal, $\frac{1}{10}$ inch thick, outwards from the surface of the bore. Thus we find that if the inmost layer of metal is stressed 25 tons to the square inch, or $2\frac{1}{2}$ tons on $\frac{1}{10}$ inch, then the next layer is stressed 2.25 tons, the next 2.04 the next 1.86, and so on. We have to find a sufficient number of layers in order that the stress borne by the whole of them may equal 37.5 tons. This calculation may be quickly performed by the Integral Calculus. But for the present purpose we will confine ourselves to simple arithmetic.* We have only to make a list of the stresses for each $\frac{1}{10}$ inch and to add it up till we get a total of 37.5 tons.

From this list (Table A) we see that even if we make the metal 6 inches thick we shall only get a total of 36.9 tons. The weight of a gun of this thickness would be prohibitive.

It will have been noted that the stress borne by the different $\frac{1}{10}$ inch layers diminishes from 2.5 tons on the inner layer down to 0.15 tons on the last. Each successive layer adds less and less to the strength of the gun, so that even if an infinite number of layers were added the strength would not be increased beyond a certain point. That is, in a gun bored from a solid block of steel a large proportion of the metal is nearly useless. This construction is therefore never used except for small mountain guns in which the powder pressure is comparatively low. Some coast defence guns, cast solid, are still in use in Sweden but these are not only enormously heavy in proportion to their ballistics, but they are far less powerful than guns of similar calibre in our own service.

In order to make the outer portion of the metal do its share of work, it is necessary to build the gun in two or more layers, each shrunk on to the one inside it. Suppose a gun made in two layers, each an inch thick, the outer being shrunk on with a tension of 5 tons per square inch. Then it is clear that the inner layer will be 5 tons stronger than if uncompressed, while the outer will be 5 tons weaker; the inner layer will have borrowed strength from the outer, which can well afford it, since, as we have seen, the stress on the outer layer due to the powder pressure is much smaller than that on the inner. This construction enables us to distribute the stresses throughout the gun, so that every part of the metal is stressed to the same extent. This, at least, would be the case if a large number of thin layers were

* NOTE—In practice, instead of summing the Barlow curve arithmetically, we take advantage of the fact that its area is equal to a rectangle on the same base and of the mean height of the curve. The mean height is the height at the geometrical mean between the inner and outer radii. Thus in a tube whose inner radius is 2 inches, and outer radius 4 inches, the mean height of the Barlow curve is the height at a point distant $\sqrt{2 \times 4} = 2.83$ inches from the centre of the tube.

used. For the stress within each layer must still remain unequal, the inside of the layer being stressed more than the outside. Some of the older guns were on this account built up of numerous layers, the shrinkage of each being regulated so that all were equally stressed. The 12-inch gun of 25 tons, for instance had six superposed layers. Guns on this system have, however, been superseded to a great extent in this country by wire-wound guns, which will be described later.

We will next consider what sort of a gun we shall obtain if we build it in two layers. From the " Barlow curve " already drawn we obtain the stress on each layer of metal $\frac{1}{10}$ inch thick in a solid block gun. When the inner layer is stressed to the (unusually high) limit which we have fixed, namely, 25 tons per square inch, or 2.5 tons on this layer, the stresses on the successive $\frac{1}{10}$ inch layers will be as in Table A. Now suppose that we make the gun with an inner tube, or A tube, and an outer tube called the jacket, each one inch thick, the latter being shrunk on with a tension of 10 tons per square inch. Then, since, the stress on the A tube is reduced by 10 tons, we can now make the thickness of the metal such that the original stress on it would have been 35 tons per square inch on the inner layer if unsupported, instead of 25 tons. Then from table A, the total stress on the A tube will be $17.04 \times \frac{35}{25} - 10$ tons, or 14 tons, and that on the jacket will be $8.13 \times \frac{35}{25} + 10$ tons or 21.4 tons, total 35.4 tons. This is below the 37.5 tons which we require. A shrinkage of 12 tons would give a total of exactly 37.5 tons; but in this case the stress on the inner layer of the jacket would be $1.06 \times \frac{37}{25} + 1.2 = 2.77$ tons, or 27.7 tons per square inch, which is beyond our 25-ton limit. Try making the A Tube 1.2 inches thick and jacket 1 inch, with shrinkage of 11 tons. Then the dimensions may be such that the unsupported stress would be 36 tons per square inch instead of 25. We have now, taking the first twelve and second ten figures from Table A: Sum of stresses $= 19.09 \times \frac{36}{25} - 11 + 7.23 \times \frac{36}{25} + 11 = 37.9$ which is slightly more than we require. The greatest stress, namely at the inner $\frac{1}{10}$ inch layer of the jacket, will be $0.93 \times \frac{36}{25} + 1.1 = 2.44$ or 24.4 tons per square inch, which is within our limit.

The nature of the process we have performed will be evident from Fig. 21. To simplify the drawing, we will take our first attempt at the solution, in which the A tube and jacket are each 1 inch thick.

Start the " Barlow curve " at 35 tons, and take the first inch of it, AB, of which the area represents $17.04 \times 35/25$ or 24 tons of stress. Cut off CB representing 10 tons from the bottom of the area; then the remainder AD represents 14 tons of stress. Now take the next inch of the same curve, EF, representing $8.13 \times 35/25$ or 11.4 tons of stress; add GH representing 10 tons, and the sum, EH, represents 21.4 tons of stress.

The maximum stress at any point is 25 tons per square inch on the inner layer of the A tube, AC, and 24.4 tons per square inch on the inner layer of the jacket, ED.

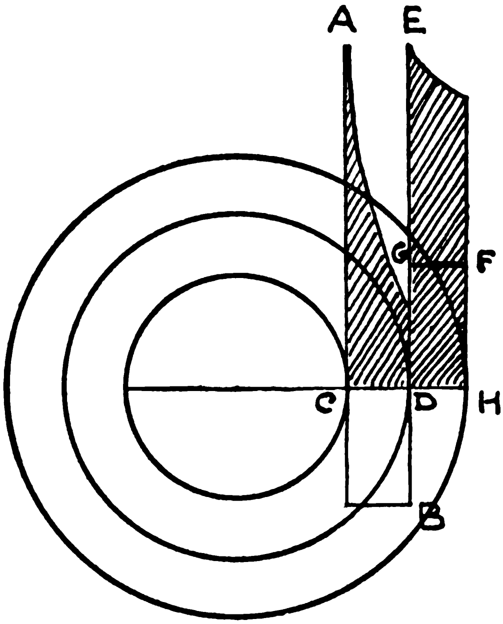


FIG. 21.

Therefore a gun built up in 2 layers will be sufficiently strong for our requirements. The thickness of the metal is calculated for say 10 points in the length of the gun, the results plotted, and curves drawn through them which gives the thickness of the A tube and jacket at any point. For instance, at the muzzle the normal powder pressure is 3 tons per square inch, therefore the gun must be able to stand 6 tons. Then, as before, the circumferential stress tending to burst the gun, will be 37.5 × 3/10 or 11.25 tons, and the total permissible stress on the two layers must be not less than this amount. Try 0.3 inch for the A tube, and the same for the jacket, with a shrinkage of 1 ton. (Note that the shrinkage may be varied as required at different points.) Then the sum of the stresses on the A tube, from Table A, is

$$(2.50 + 2.25 + 2.04) \times \frac{26}{25} - 1 = 6.05 \text{ tons.}$$

while the sum of those on the jacket is

$$(1.86 + 1.70 + 1.56) \times \frac{26}{35} + 1 = 6.32 \text{ tons.}$$

Total 12.37 tons.

The stress on the inner 1/10″ layer of the jacket is

$$1.86 \times \frac{26}{25} + 0.1 = 2.03 \text{ tons}$$

or 20.3 tons per square inch, which is within our 25-ton limit.

It need hardly be said that gun-makers do not proceed by such a very elementary process as reckoning the stress for every 1/10 inch of metal, adding up the results, and then taking enough 1/10 inch layers to give the desired total. They use the gun-maker's formula, which enables the calculation to be performed more accurately and with less labour. But the simple arithmetical method is given here in order to show that there is really no mystery underlying the formidable-looking formulæ given in the Text Book of Gunnery. These are plain arithmetical truths expressed in a general form convenient for calculation. The same results could be arrived at equally well by patience and the multiplication table.

Weight of the Gun.

If we take our gun as a frustum of a cone from the muzzle to the point where the highest pressure occurs, say a foot down the bore, and thence as a cylinder to the breech, then by the mensuration formulæ at the end of this book the weight works out at 11.85 cwt. Roughly speaking, the guides and the breech-block will nearly balance the hollow due to the inward curve of the chase, so that the weight will be about 11 cwt. This is decidedly on the heavy side for a field gun, since the two heaviest field guns, the French and the English, weigh only 9 cwt. each. We will therefore see what reduction can be obtained by the wire-wound construction.

Wire-Wound Guns.

It would be possible to build up an excellent field gun, of minimum weight, by making it in say four $\frac{1}{4}$-inch layers, shrunk on so as to distribute the stress on firing equally throughout the four layers. Such a gun, however, would be very expensive. The same result can be arrived at more cheaply and more efficiently by the wire-winding system, invented by Mr. James Longridge. A steel ribbon $\frac{1}{16}''$ thick and $\frac{1}{4}''$ wide is wound on to the A tube in successive layers with gradually decreasing tension.

It would first appear that the tension ought to be an increasing one to produce equal stresses throughout. But this is not so, chiefly because each successive layer compresses those below it as it is wound on, thus making the inner layers looser and the outer layers tighter. The relative amount of tension in each layer depends upon the elasticity, or compressibility, of the steel used, and is worked out mathematically in the Text Book of Gunnery, 1907, page 176.

Since a large number of layers are used, this system gives an ideal distribution of stresses throughout the layers of wire. Moreover the tensile strength of steel ribbon is over 100 tons per square inch, while that of the strongest gun-steel ordinarily used does not exceed 50 tons. Hence a wire-wound gun can be made lighter for the same strength than a built-up gun.

In the presence instance, suppose the gun is made of an A tube wound with wire. We will assume that the maximum stress on the A tube on firing is to be 25 tons per square inch, and that on the wire 60 tons per square inch. The wire is to be wound on so as to give a total supporting stress on the A tube of 20 tons. The total stress on firing on the A tube and wire, at the point where the powder pressure is 10 tons per square inch, is to be 37.5 tons as before.

Try an A tube 0.7″ thick (in addition to the lands of the rifling.) Now a supporting tension of 20 tons on 0.7″ is 28.57 tons per square inch. Therefore we may make the thickness of the gun such that the stress at the surface of the bore would be 28.57 tons per square inch more than our 25-ton limit if the A tube were unsupported. Therefore we can start the " Barlow curve " at $25 + 28.57 = 53.37$ tons. Multiply the figures in Table A by $\frac{53.57}{25}$ and we have :

TABLE B.

5.36	
4.82	
4.38	
3.98	
3.64	
3.34	
3.07	28.59
2.85	
2.64	
&c.	
&c.	

Then total stress on A tube is 28.59 — 20 = 8.59 tons.

Now the wire is to be wound on with tension such that the stress on firing throughout the wire is the same, namely, that of its inner layer, or, from the accompanying table, 2.85 tons on 1/10 inch. We have already 8.59 tons on the A tube, and the whole of the wire is to provide 20 tons of supporting tension, leaving 8.91 tons to be added. Each 1/10″ layer of wire adds 2.85 tons, so that if we put on five 1/10″ layers of wire we shall have more than we require.

Then if the total stress on the wall of the gun on firing be 37.5 tons (which, it will be remembered, is double the stress for the normal powder pressure) we shall have 20 + 8.91 tons on ½ inch of wire or 57.82 tons per square inch on the wire, which is within the 60-ton limit which we have laid down.

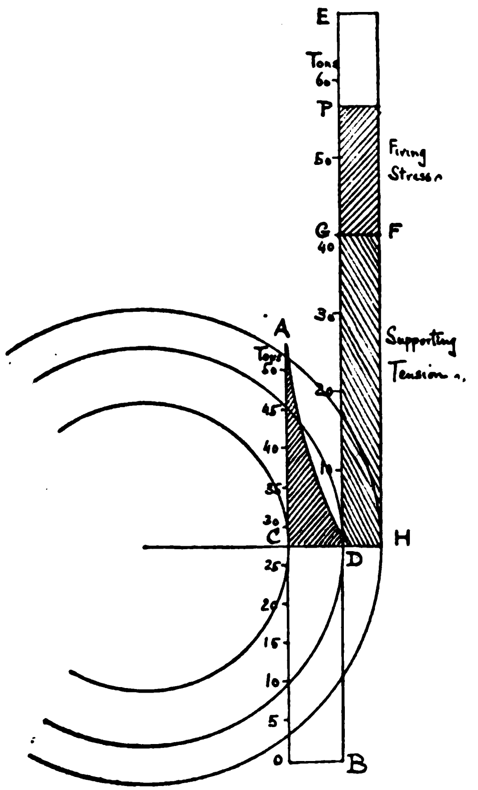


FIG. 22.

The construction at which we have arrived is shown graphically in Fig. 22. We start the "Barlow curve" at 53.57 tons, and take the first 7/10 of an inch of it, AB, of which the area represents 28.59 tons of stress. Cut off CB representlng 20 tons from the bottom of the area; then the remainder AD represents 8.59 tons of stress. Now take the rectangle EF, ½ inch wide, representing 5 × 2.15 or 14.25 tons of stress; add on GH equal to CB representing 20 tons, and the sum EH, represents 24.25 tons of stress. The actual firing stress on the wire will be only 8.25 tons (represented by PF) besides the supporting tension, not 14.25 as above, but we have had to take ½ inch of wire, as otherwise the supporting tension, together with the firing stress, would have been over the 60-ton limit.

When the wire is all on, the tensions on the different layers of wire, which make the stresses on firing equal throughout, are if we disregard the initial tension which supports the A tube, inversely proportional to the stresses given by the " Barlow curve." Since the stress produced by firing is less on the outer layer of wire than on the inner layer, the tension of the outer layer has to be greater in

order to support the inner layers and so do its fair share of the work. But, as already explained, the original winding tension with which the wire is put on is less on the outer layer.

Therefore, as regards resistance to bursting, our wire-wound gun will be strong enough if made $0.7 + 0.5 = 1.2$ inch thick at the point where the powder-pressure is 10 tons per square inch, instead of 2.2 inches as before. This, if it could be carried out, would reduce the weight of the gun to $11 \times \frac{1.2}{2.2}$ cwt or 6.0 cwt. Unfortunately this is not a practical construction. The A tube would be only $7/10 \times 0.3$ or 0.21″ thick at the muzzle, and would be so deficient in stiffness as to vibrate considerably, causing inaccurate shooting. In practice it is always found necessary to put a jacket over the wire, partly to protect it but principally to stiffen the gun. Since however in a field gun the support afforded to the A tube at the muzzle by the jacket is quite sufficient without any wire, the wire is not carried as far as the muzzle. Thus in the 18 pr. the wire is only carried forward about a third of the length from the breech. That is, a wire-wound field gun is built up as a two-layer gun for the greater part of its length, and as a jacketed wire-wound gun for the remainder. It is not easy to shrink the jacket over the wire within accurate limits of shrinkage, and therefore the part of the jacket over the wire is not relied upon to contribute to the strength of the gun. It must however be thick enough to stiffen the gun, to support the guides and horn for attachment of the buffer, and (in the 18 pr.) to take the breech-piece which carries the breech block.

In our present gun we will take A Tube and jacket each 0.3″ thick at the muzzle, besides the muzzle swell, which is added principally to prevent damage if the muzzle strikes the ground in travelling. At the point where the powder-pressure is 10 tons per square inch the jacket may be ½ inch thick, so that we shall have a total thickness of metal of 1.7 inch instead of 2.2 iuches in the two-layer gun. This reduces the weight previously calculated by slightly more than 1 cwt., so that our wire-wound gun will weight 10 cwt.

This is about as light as it is possible to get a 20 pr. with M.V. of 2000 fs., and this light weight has only been attained by making the gun inordinately long, so as to get high efficiency out of a small powder charge, and by using stresses on the metal higher than are allowed in our service.

Shrinkage.

To afford the necessary support, the jacket is made smaller inside than the outside diameter of the A tube; it is then expanded by heat, slipped on, and cooled from one end, so that it grips progressively from one end to the other. In some field guns the A tube and jacket are tapered and the jacket is forced on cold by pressure applied to one end. The difference between the internal diameter of the jacket and the external diameter of the A tube is arrived at by knowing the amount to which the metal of the jacket will stretch, and that of the A tube be compressed, under a given stress. This may be calculated by the formula given on page 168 of the Text Book of Gunnery, but it is usually arrived at by experience.

Longitudinal Tensions.

These are of no great importance, since if the metal be strong enough to resist the pressure tending to burst the gun it is amply strong enough to resist that which tends to pull it apart endways. For instance, in the gun which we have been describing, the A tube is 0.7″ thick at the point where the powder-pressure is 10 tons per square inch. Then the longitudinal pull is

$$10 \times \pi \left(\frac{3 \cdot 75}{2}\right)^2 \text{ or } 110 \text{ tons,}$$

while the strength of the A Tube, up to the yield point of 25 tons per square inch, is

$$25 \times \left\{ \pi \left(\frac{3 \cdot 75}{2} + 0.7\right)^2 - \pi\left(\frac{3 \cdot 75}{2}\right)^2 \right\}$$

or 244 tons.

so that there is a considerable margin to spare on the A Tube alone.

Ehrhardt System.

The three methods of gun-construction above described are the only ones used in our own service. There is, however, another method, known as the Ehrhardt system. In this the A tube and jacket are each formed from a solid ingot into which a mandril is forced when red-hot. This process leaves the inner layers of the metal in a state of initial compression, and so, to some extent, serves the purpose of the wire-winding system. This process is not applicable to heavy or medium guns. The only example of it in our own service is the 15 pr. Q.F. gun, made by Messrs. Ehrhardt.

CHAPTER X.

RIFLING.

Rifling is a means of imparting rotation to the shell. In all modern guns this is effected by cutting helical grooves down the bore, leaving raised ribs called "lands" between them. A band of soft copper is secured round the shell near the base. On discharge the shell with its copper driving-band is projected up the bore; the ribs cut into the soft copper and force the shell to follow their helical course and to rotate. This rotation continues, somewhat diminished by the friction of the air, to the end of the shell's flight.

Other means of making the shell rotate have been used, such as the tail with spiral vanes which rotated the torpedo shell fired from the Zalinski dynamite gun.

The only method of rifling now in use is, however, the polygroove system (so called from the large number of small grooves) and the copper driving-band.

Object of Rifling.

Any rapidly-rotating body tends to preserve the direction of its axis of rotation—that is, to keep in the same direction in which it pointed when first made to rotate. A familiar instance of this is the spinning top.

Not only does a spinning body tend to preserve the direction of its axis of rotation when left alone, but it actively resists any attempt to change that direction.

Thus, if we attempt to upset a spinning top by striking it with a ruler, we shall find some difficulty in doing so. Instead of overturning, the top will fly off sideways, still keeping vertical.

This property of rotating bodies is turned to account to make the shell travel point first during its flight. But for the spin given to the shell it would soon turn over and fly sideways, when its direction would become erratic and its range would be much reduced.

The object of rifling may, then, be said to be to enable a gun to fire an elongated projectile with accuracy.

Advantages of Elongated Projectiles.

Since a shell three calibres long has a cross-section only one third of that of a spherical shell of the same weight, it can be fired from a much smaller and lighter gun. And since it only opposes to the air a resistance one-third of that of the spherical shell, it ranges much further. And moreover since in penetrating an obstacle it makes a hole only one-third the size of that made by a spherical shell, it will penetrate more readily.

These advantages may be said to be due to rifling, which renders it possible to use the elongated shell.

Twist of Rifling.

A spinning top is acted on by its weight, which constantly tends to make it fall flat, and its energy of rotation, which keeps it vertical. When, owing to the friction of the peg of the top, the energy of rotation is sufficiently diminished, the top overbalances.

Now, with a shell, the force tending to overturn it is the pressure due to the resistance of the air, and that tending to keep it straight is the rotation due to the rifling. The former tends to constantly diminish as the shell expends its velocity in overcoming the resistance of the air; but the spin is affected only by the surface-friction between the shell and the air, and reduced is to a less extent. For flat trajectories, it follows, then, that if we give the shell enough spin to keep it straight at starting, this will suffice to keep it point foremost to the end of its flight.

Minimum Twist.

The longer the shell in proportion to its diameter, the greater the amount of spin required. It will be afterwards seen that it is desirable not to allow an undue amount, as this increases the lateral curvature of the path of the shell.

A table of minimum twist of rifling required to keep steady a shell of any given length will be found on page 187 of the Text Book of Gunnery, 1907. As an instance, it may be noted that a shell 3½ calibres long requires a twist of at least one turn in 36 calibres to keep it steady.

Uniform and Increasing Twist.

It will be readily understood that if a heavy shell has a high velocity of rotation suddenly forced upon it, this must cause a severe strain both on the shell and on the gun. To avoid this, the grooves of the rifling are made to run at first straight down the gun, gradually increasing in inclination or "pitch" till the full velocity of rotation is attained. This is known as an "increasing twist," in contradistinction to the older "uniform twist," in which the pitch of the rifling was the same all down the bore.

The increasing twist has, however, the disadvantage of causing greater friction in the bore and consequent loss of velocity. For the indents made by the lands in the driving-band have to be forcibly displaced as the shell travels down the bore and the inclination of the land alters. For this reason the uniform twist has been adopted in the 18 pr. and 13 pr. guns, and in the French service field gun.

Foreign nations mostly use the increasing twist, because the reduced stress on the shell enables the walls to be made thinner, thus increasing the bullet-capacity. The Krupp and Ehrhardt field shrapnel contain 50 per cent of bullets.

As a good example of modern increasing-twist rifling, we may take the 15 pr. Q.F. gun, the rifling of which is officially described as follows—

System—Polygroove.

Twist—Increasing from 1 turn in 60 calibres at breech to 1 turn in 25 calibres at 5.8 inches from muzzle; remainder uniform, 1 turn in 25 calibres.

Length—77.67 inches.

Position of the Driving-band.

At first sight it would seem desirable to put the driving-band as near the centre of gravity of the shell as possible, but in practice this is not the case. The walls are too thin at the centre of the shell to carry the driving-band. Moreover the body of the shell can never be a close fit in the bore, and after the driving-band had emerged from the muzzle it would be followed by some 6 inches of ill-fitting body, with the powder-gases escaping past one side of it, which would unsteady the shell. Accordingly the driving-band is always set as far back as possible, leaving only sufficient metal behind it to afford a grip for the cartridge case.

Forward steadying-band.

The unsteadiness or oscillation of the shell in the bore, due to its imperfect fit, is a serious cause of inaccurate shooting. Attempts have been made to overcome this by fitting a forward band in addition to the driving-band. It is said that the new Austrian field shell has a steading band of this nature. The subject is beset with difficulties. If an increasing twist is used, the forward band must on no account take the rifling. If the forward band is to be a good fit in the bore, then the lands must be eased at the breech in order to enable the shell to be rammed home. The walls have to be thickened at the shoulder to take the band. In spite of these difficulties, it would seem worth while to try the steadying band in field guns with uniform twist of rifling, in order to obtain increased accuracy for fire at shielded guns. The Armstrong 12 pr. R.B.L. field gun with lead-coated projectile was a far more accurate weapon than the 9 pr. with studded shell which succeeded it.

The French 75 mm. field gun, which is rifled with uniform twist, has a shell with 3 separate driving-bands about 1 inch apart. This is said to give good shooting.

DRIFT.

This is a very difficult and complicated subject. We know that the service shell tends to deviate from the line of fire in a curve to the right, but we do not fully understand the laws governing this motion.

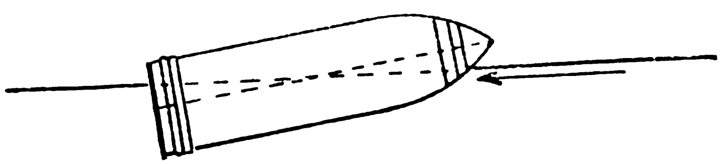


FIG. 23.

Although the effect of the resistance of the air tends to keep the shell pointing in the direction of its motion, yet the spin of the shell constantly resists this tendency, and tries to keep the shell parallel to its original direction, as in the above figure. The result is a compromise, and the shell travels with its nose cocked in the air, well above the line of the trajectory. It will be apparent from the figure that the full pressure of the resistance of the air comes below the point of the shell.

Now if we remember that the shell, viewed from behind, is spinning in the direction of the hands of a clock, then it will be evident that its friction against the air resistance, which takes it below the centre, must tend to make the shell gradually deviate to the right. And since the spin of the shell diminishes more slowly than the forward velocity, therefore the path of the shell curves more and more to the right.

Thus if we suppose that the spin of the shell carries it ten feet to the right every second, then in the first second the shell will travel say 1500 feet forwards and 10 feet sideways, and will have acquired a side velocity, at right angles to the line of fire, of 20 feet per second. During the next second this side velocity will increase to 40 feet per second, during the next to 60 feet, and so on ; while all the time the forward velocity will be decreasing. It is quite con- conceivable that if the range were long enough and the twist sharp enough the shell would end by drifting almost square across the line of fire.

A good distance of drift is the behaviour of a sliced golf ball. Here we have a projectile roughened so that the effect of the twist makes itself fully felt, a comparatively low velocity, and a sharp spin ; and the result is often that the ball pitches nearly as far off the course as it carries from the tee.

It must not be supposed that the above is either a full account or a mathematically correct statement of the behaviour of a rifled projectile. It merely furnishes a working hypothesis sufficiently near the truth for the purposes of the practical gunner. Students desiring fuller information are referred to the Text Book of Gunnery.

Persistence of Spin.

It was formerly supposed that the spin of the shell was but little affected by the air-resistance, and that, for flat trajectories, the spin continued almost undiminished to the end of the shell's flight. Recent experiments with mechanical fuzes depending for their action on the spin of the shell have caused this view to be modified. It is found that a Q.F. field shell loses about 10 per cent of its spin at 3000 yards, and about 20 per cent at 5000 yards.

The reasons for this are as follows :

(i.) Part of the spin is expended in overcoming the surface friction of the shell against the air. It must be remembered that the shell is constantly passing through a wave of air compressed by its own forward motion. As may be seen from spark photographs, this wave of compression extends beyond

Page 78 & 201.—The 18 pr. shell loses 4% of its spin at 1000 yards, 7½% at 2000, 11% at 3000, 14% at 4000, 16½% at 5000, and 19% at 6000 yards.

the shoulders of the shell and a considerable distance down the body. The friction caused by the shell rotating in this compressed air is much greater than it would be in air at the normal pressure.

(ii.) Part of the spin is expended in giving the lateral drift to the shell. Suppose a shell drifts two degrees at 4000 yards, it will have moved 400 feet laterally in 10 seconds, its mean lateral velocity will be 40 fs., and its final lateral velocity 80 fs. If the shell weighs 15 lbs, the energy consumed in giving it a lateral velocity of 80 fs. will be $\frac{15 \times 6400}{64.4}$ or nearly 1500 foot-pounds. How much of this is at the expense of the forward velocity, and how much at the expense of the spin, it is difficult to say.

(iii.) When the shell rotates eccentrically, and is noisy in flight, the spin has to do a considerable amount of work in setting air-waves in motion. Theoretically, therefore, a noisy shell should drift less than a steady one, since it loses its spin earlier. But the flight of a noisy shell is usually so erratic as to render it difficult to test this point.

(iv.) If a shell were fired in vacuo, it would maintain its original angle to the horizontal all the way, and would come down on one edge of its base, since there is nothing to make it change its direction. When it is fired in air, its cylindro-conical shape keeps it more or less point first all the way, at least for flat trajectories. Now it requires a considerable effort to change the direction of the axis of a rotating body, and this effort is exerted partly by the forward motion of the shell, partly by its spin, re-acting on the cushion of compressed air surrounding the shell. It is therefore not surprising to find that a howitzer shell fired at a high elevation and long range has but little spin left at the end of its flight, since if fired at 45 degrees the axis of rotation has been deflected through more than a right angle.

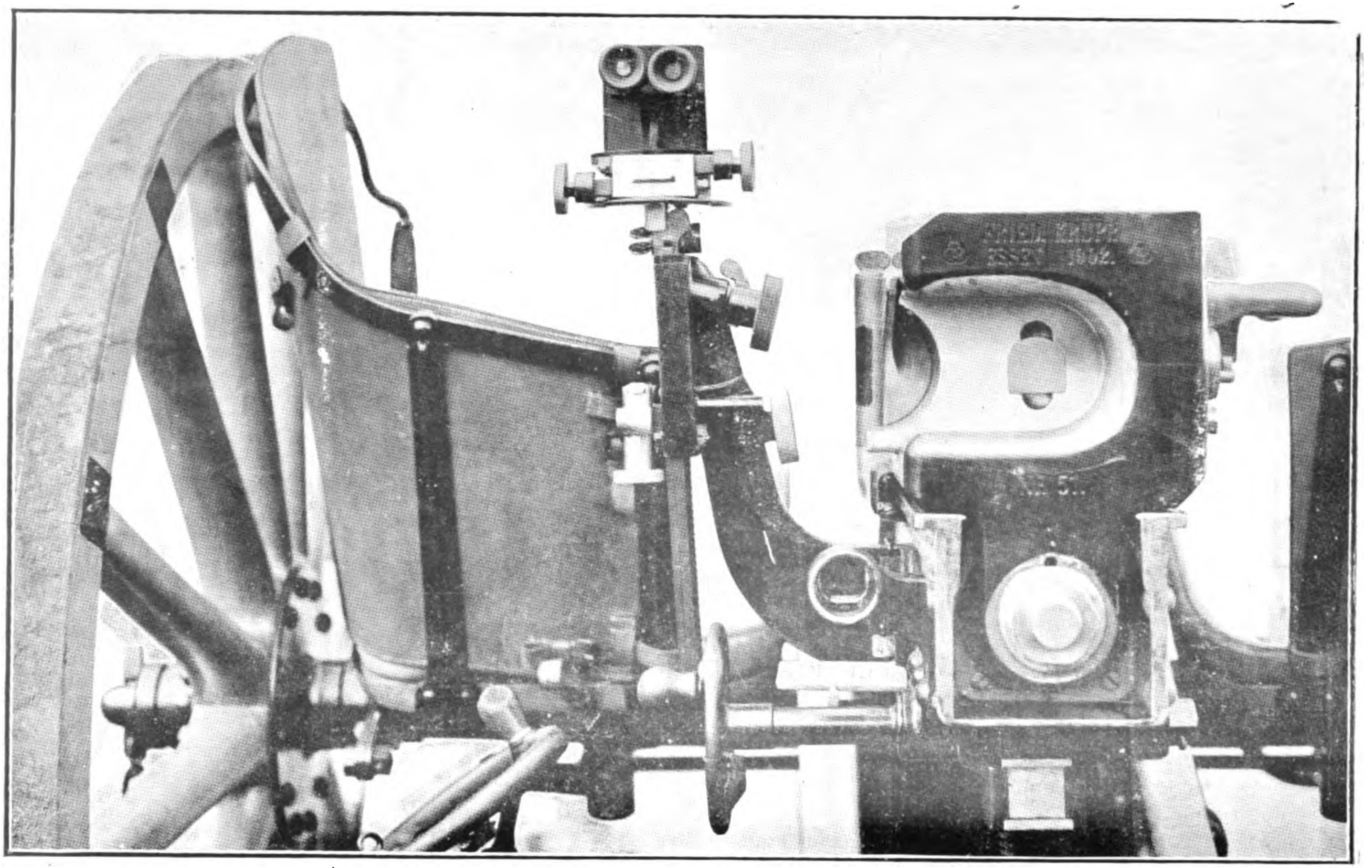
Flight of a Howitzer Shell.

It is sometimes possible to observe the flight of a howitzer shell, fired at full elevation, through a telescope. The following action is observed to take place: At the vertex of the trajectory, the shell has but little forward velocity left, while the spin is still considerable. The shell is then pointing upwards at about 20 degrees to the horizontal. It is probable that at this period a great deal of drift takes place. As the shell begins to descend the velocity increases, and the shell begins to point downwards. It does not however immediately settle down to the tangent to the trajectory, but there is a period of unsteadiness during which the shell oscillates through as much as 15 degrees above and below the trajectory.

As the downward velocity increases the shell becomes steady again, until on impact it is usually pointing some 5 degrees above the trajectory. The period of oscillation is very noticeable in star shell fired from howitzers; when the shell are burst high, the stars issue in unexpected directions, no two rounds alike.

Kiting.

It is frequently found that shells range further than they should do, according to the most careful calculations. If throughout its flight the shell is pointing above the trajectory, as in Fig. 23, it is clear that the effect must be the same as when the lifting plane of an air-ship is inclined upwards, that is, to produce a gliding action tending to keep the shell off the ground. The discrepancy between the actual and calculated flight is therefore usually ascribed to kiting.



KRUPP DIAL SIGHT

CHAPTER XI.

SIGHTS.

The theory of the action of sights is simple enough, especially when applied to the arc sight which has superseded the old tangent scale.

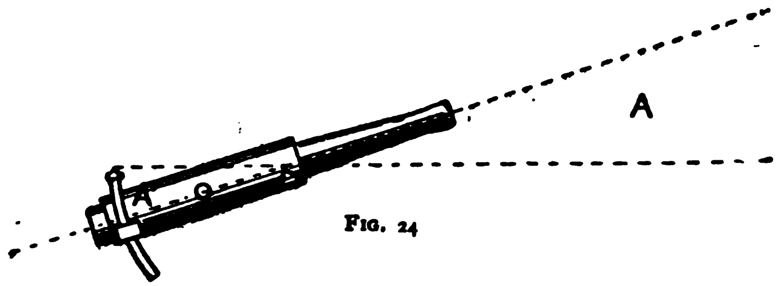


FIG. 24

Thus, in the figure, the elevation A above the target which is given to the gun in order to enable the shell to reach the target is equal to the angle A′ measured on the arc sight. In this instance the line of sight, when the back-sight is down, is on a level with the axis of the piece; but if any other position for the sights is more convenient, these may be set higher or lower, further to the front or further to rear, if only the line of sight with back-sight at zero is *parallel* to the axis of the piece. It is, in fact, usual to set the sights as high as conveniently possible in order that the line of sight may clear intervening cover high enough to partially conceal the gun.

Deflection.

Suppose that the shot, owing to the wind or other causes, has fallen to the left of the target, then the gun must be pointed to the right of the target in order to shift the point of impact to the right. Then, if the gun be looked down upon from above, as in the figure,

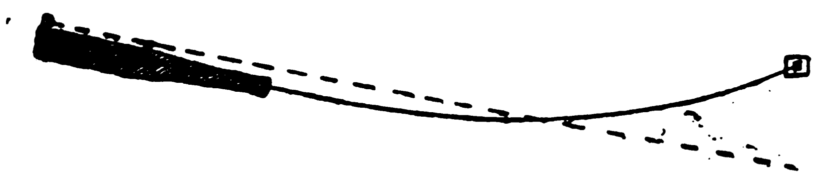


FIG. 25.

the line of sight, with the deflection leaf in the middle, will pass to the right of the target. To bring the line of sight on to the target we have to shift the moveable leaf, with the notch in it, over to the right. This is called "giving right deflection."

The amount of deflection is arrived at by estimating the lateral distance to the left of the target at which the shot fell, and expressing this in degrees and minutes. To do this we use the gunner's rule, which is nearly correct for small angles, that "a minute is equal to an inch at 100 yards;" that is, that one yard of error requires 36 minutes to correct it at 100 yards, or 3.6 minutes at 1000 yards. This is expressed in the rule "Reduce the error to inches and divide by the number of hundreds of yards in the range."

Deflection for Drift.

We know that the effect of the rotation of the shell is to make it deviate more and more to the right of its original direction as it flies down the range. The greater the range, therefore, the more we must aim to the left of the target to make a hit; that is, the more left deflection we must put on.

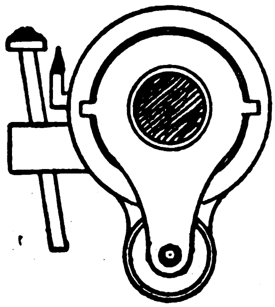


FIG. 26.

This is conveniently effected by setting the back-sight at an angle in the gun, so that when right down it gives no deflection, but the higher it is raised the greater the distance of the notch to the left of the original line of sight.

Since the amount of drift is not in proportion to the range, but is greater at long ranges than short ones, this method of correcting for drift by inclining a straight back-sight is not accurate. At most we can only give an average correction in this way, which is too great at short ranges and too small at long ones. If the back-sight could be curved sideways a closer approximation might be attained, but for a field gun this refinement would not be worth the additional complication.

In some Q.F. equipments an average correction for drift is given by raising the right trunnion of the cradle above the left. Take an extreme case and suppose the right trunnion six inches higher than the left and the gun elevated from zero to 45 degrees; then it will be plain, on consideration, that the more the gun is elevated the more it will point to the left of its original line.

Difference of Level of Wheels.

Suppose the back-sight raised one foot and the gun on sloping ground so that the right wheel is much higher than the left. Then the effect of the difference of level will be to tilt the sight over to the left, so that the notch is considerably to the left of its position when the back-sight is down. We shall unconsciously, in fact, be giving left deflection and the shell will pitch to the left of the target. To correct this it is necessary to give right deflection. The gunner's rule for this, which is sufficiently accurate for practical purposes, is:

> "Multiply the number of inches difference of level of wheels by the number of degrees of elevation, and give that number of minutes of deflection towards the higher wheel."

Instead of taking the number of inches of difference of level we may set the clinometer crosswise on the breech and measure the inclination in degrees. This, multiplied by the degrees of elevation, will give the required deflection.

By taking an extreme case it will be seen that the shell will tend to go to the side of the lower wheel; for if the back-sight be raised to 10 degrees and the gun turned over on its side with the right wheel on top, then the gun, if previously layed on the target, will now be pointing 10 degrees to the left of it.

In some B.L. Mountain Battery equipments, intended to be used on rough ground, this error was obviated by setting the straight tangent scale in a socket pivoted parallel to the axis of the piece, and putting a heavy knob of metal on the end of it, so that, seen from behind, it always hung straight up and down.

Theory of Scott's Sight.

Col. Scott's telescopic sight has for many years done good service in the Horse and Field, Now, however, that the sights are attached to the non-recoiling portions of the carriage, we are able to fix the telescope directly to the arc sight or rocking bar, and a separate telescopic sight is not required. The constructional principles involved are however of importance, especially on account of their application in the Dial Sight.

Scott's Sight consists of a telescope mounted in a steel frame. This frame has longitudinal trunnions fitted into Vs on the gun. These Vs are so arranged that the axis of the trunnions of the sight-frame is exactly parallel to the axis of the gun. By means of a cross level, the frame can be so adjusted that the cross axis on which the telescope is mounted is truly horizontal.

This at once eliminates any error due to the sights being tilted owing to difference of level of wheels, since once the sight-frame is levelled the telescope moves up and down in a vertical plane. It also eliminates any error due to one trunnion of the gun being higher than the other; for, suppose the sight set and levelled, and the gun elevated till the telescope points at the target, and then suppose the sight immoveably suspended in the air in that position; then, since the axis of the gun must always remain parallel to the longitudinal axis of the sight-frame, the gun and carriage might be revolved about the trunnions of the sight-frame without altering the quadrant elevatian of the axis.

MODERN Q.F. SIGHTS.

The improvements in the accuracy and rate of fire of modern field-guns have led to the introduction of more perfect sights. In all of these the object of the improvements is to facilitate the layer's work so as to make laying easier, quicker, and more accurate, and to avoid as far as possible the chance of mistakes.

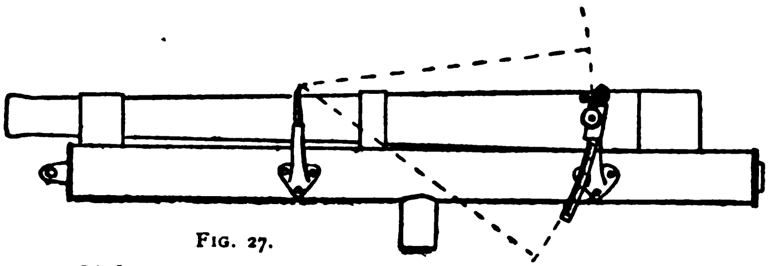


FIG. 27.

The Arc Sight.

With the advent of the Q.F. gun, the straight tangent scale was superseded by the arc sight, invented by Major Corrodi of the Italian Artillery. The bar of this sight is a portion of a circle struck from the tip of the foresight, A longitudinal level is fixed at right angles to the top of the bar, that is, on a radius of the above circle. Then if the sight-bar be drawn out of its socket till an arc of 10 degrees is exposed, the level will have been tilted through the same angle. This enables the arc sight to be used as sight-bar and clinometer in one. Besides this movement, the longitudinal level is capable of being elevated or depressed with reference to the sight-bar, the angle through which it is moved being recorded by a micrometer or helical drum. This motion is used from laying behind cover. Suppose that it is desired to fire at a target invisible from the battery and on a higher level, so that the angle of sight from the gun to the target is + 3 degrees. Then if the longitudinal level be set to + 3 degrees, and the arc sight to the range—say 3000 yards—and the gun elevated till the bubble is centred, the effect will be to give to the gun an elevation of 3 degrees plus the elevation required to carry the shell 3000 yards on the level.

The longitudinal level may be fixed to any part of the sight-bar, and in modern equipments it is usually set low down, so that the layer can look down upon it without shifting his position. See Fig. 28.

The sight-bar is raised and lowered in its socket by a pinion engaging with a rack formed upon it. This pinion can be disengaged when it is desired to quickly raise or lower the sight. In some equipments a drum is attached to the pinion, and the ranges in yards are marked on it in a helix; this gives a greater length of scale and more open graduations than if the ranges were marked only on the bar. The Krupp sights (*see Plate*) have an inclined non-slipping pinion. The end, not the side, of the pinion engages with the rack, and one turn of spiral thread is cut on it which engages with the curved teeth of the rack. Owing to the inclination of the pinion, only the lower part of the spiral thread engages with the teeth. The effect is to raise the bar one tooth for every turn of the pinion.

Shifting Zero.

In Germany, the fuze is corrected by shifting the trajectory, although the sights continue to be set to the same range. (See Chapter XXIV.) For this purpose German arc sights are provided with a shifting zero. The sight-socket is fitted with an inner socket, which carries the index by which the sight is set, and which can be raised and lowered by a separate pinion. This may be noticed in the illustration of the Krupp sights. (See Fig. 28.)

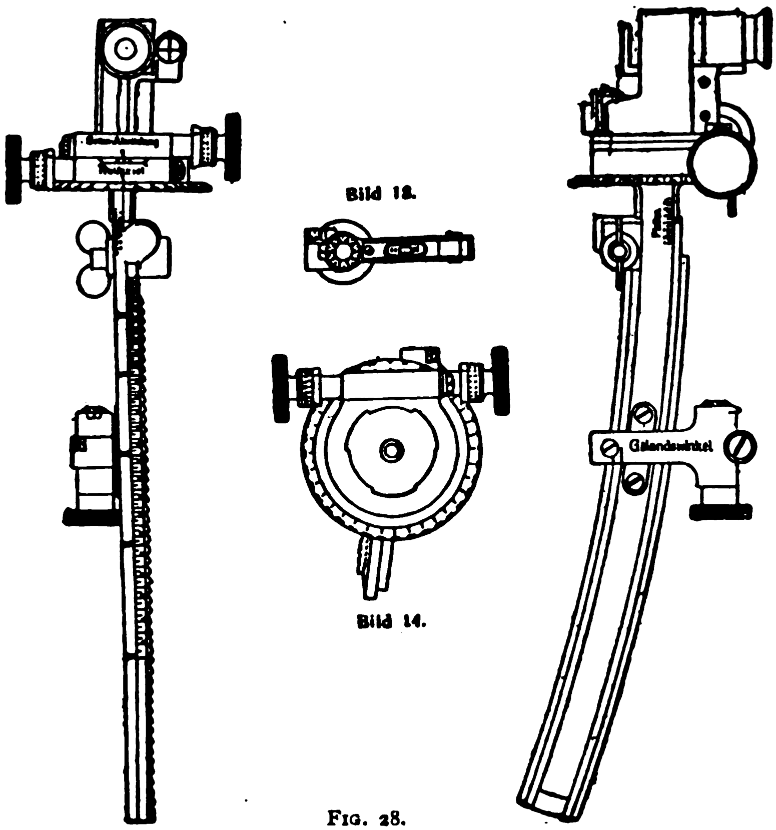


FIG. 28.

KRUPP ARC SIGHT.

Deflection.

In order to shift the point of aim laterally to correct for difference of level of wheels or for wind, the notch of the back-sight is formed in a piece of bronze capable of sliding laterally along a scale. Its motion is controlled by a traversing screw with micrometer head.

Reciprocating Sights.

The principle of Scott's sight, already explained, can be applied to the arc sight by pivoting the sight-socket parallel to the axis of the gun. By means of a transverse level (called the "cross level") and a tangent screw, the socket can be revolved about its pivot so that the arc sight is brought into a vertical plane, whatever the difference of level of the wheels. This device is used in several equipments, such as the Austrian Q.F. field gun. It is used with all the forms of sight described below, except in those carriages with independent line of sight in which the sight is on the intermediate carriage, or its equivalent. In these, the longitudinal pivot of the socket is not parallel to the axis of the gun, except when layed point-blank, so that the reciprocating principle is not applicable.

The Telescopic Sight.

Except in the panorama sight, which is a special form of telescope, this is merely a sighting telescope attached to the open sight and moving with it. We, in England, use a plain straight telescope; other nations mostly use a prismatic telescope, similar to one barrel of a Zeiss field glass. In the Plate of the Krupp arc sight, a second eyepiece will be seen; this is the finder, and consists of one barrel of an ordinary non-prismatic field-glass, magnifying about 2 diameters. Cross-wires in the finder were found unnecessary. In Fig. 28, which represents an older pattern, the finder is an open tube with cross-wires. The usual power of the sighting telescope is about × 4. There is some difference of opinion as to the best form of cross-wires. A pair of pointers, vertical and horizontal, is good, and Messrs. Goerz have a good pattern with interrupted cross lines leaving a clear space in the centre.

The Rocking Bar Sight.

A convenient means of constructing a telescopic sight is to connect the foresight and the back-sight by a straight bar upon which the telescope is fixed. A further step in advance is to attach the fore-sight and the back-sight notch to the bar and mount the bar on a horizontal pivot near the centre. This constitutes a "rocking bar."

These sights are convenient to use with a shielded field gun, where the space behind the shield is limited.

An excellent form of rocking bar, made by Messrs. Ehrhardt, is shown in attached sketch (Fig. 29). The bar is pivoted upon the

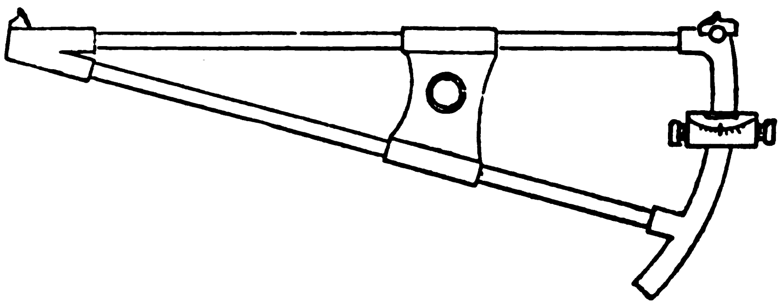


FIG. 29.

trunnion of the cradle (which does not recoil) and is elevated and depressed by a worm wheel or pinion engaging witn its curved base.

When used with a telescope, the rocking bar has the advantage of dispensing with the small screw-gear and minute graduations used with a telescopic sight of the old pattern, and thus forms a serviceable and accurate military machine.

In carriages which have not the independent line of sight, the cross pivot of the rocking bar is itself set on a pivot parallel to the axis of the piece and fixed to the cradle trunnion. The bar then takes the place of the telescope of the Scott's sight, and can be cross-levelled to eliminate difference of level of wheels in the same manner.

To give deflection, a second bar, traversing on a vertical pivot, is set immediately above the main bar. It is to this traversing bar that the foresight, back-sight notch, and telescope are attached.

Ehrhardt Traversing Foresight.

Messrs. Ehrhardt have a rocking-bar sight which has no traversing bar. In place of this, the foresight is on a transverse slide on the main bar. This slide is controlled by a cam on the side of the cradle, against which it is pressed by a spring, so that when the rear end of the bar is raised with respect to the cradle in order to lay with elevation, the foresight moves over to the right, which is equivalent to putting on left deflection.

By suitably cutting the cam, the true drift correction for any elevation is given, instead of the mean correction abtained by inclining the sight or the cradle trunnions. A similar correction may be applied to the traversing bar by making its vertical pivot eccentric and controlling the rotation of the pivot by a cam, or by setting the vertical pivot, instead of the foresight, on a lateral slide.

The Dial Sight.

In order to lay a gun from behind cover, it is necessary to have a sight which enables the gun to be layed for direction on an aiming point in flank or in rear.

The distinctive feature of the dial sight is the circular graduated base-plate, on which a short telescope or sighted ruler is pivoted so that it can be turned in any direction. Besides the main graduations on the base-plate there is a separate deflection scale on which corrections of line for each individual gun can be set.

The base-plate can be mounted on an arc sight as in Fig. 28, or on a rocking bar, or on a separate pedestal as in the German Q.F. gun. (See Part IV.)

The best method is to mount it on the reciprocating principle, as in Scott's sight. The base-plate is attached to a pedestal on the cradle by a hinge accurately parallel to the axis of the gun; above this there is a second hinge at right angles to the first. Then whatever be the difference of level of the wheels, the vertical plane passing through the zero line of the scale is always parallel to that passing through the axis of the gun. And when the base-plate is levelled the telescope or sight-vanes will enable us to measure the true horizontal angle between the line of departure and the aiming-point.

And since the levelled base-plate affords a true horizontal plane from which to measure the quadrant angle of the gun, then if to the transverse hinge we apply a device for measuring angles, such as a helically-graduated drum or a tangent screw, we have a means of laying the gun also for quadrant elevation.

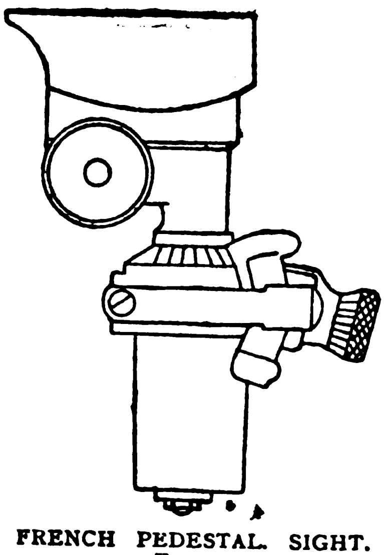
The Pedestal Sight. (Fig. 30.)

This is a special form of the dial sight, and is used only with the "independent line of sight" described below.

It consists of a standard or pedestal attached to the "intermediate carriage," and supporting a telescope fixed at right angles to it. The telescope is mounted on a graduated circular table on top of the pedestal, and can be traversed horizontally through a complete circle. This sight can be used either for aiming directly at the target or for aiming at an auxiliary mark to right, left or behind the gun. When used for direct laying, the telescope remains fixed at right angles to the pedestal, the inclination due to the angle of sight being given by elevating or depressing the intermediate carriage to which the pedestal is attached; when the sight is directed at an aiming point to a flank, the telescope itself is elevated or depressed by a tangent screw. In the latter case the gun elevation is given by clinometer.

One advantage of this sight is that by lengthening the pedestal it can be used for direct fire by a layer standing erect, or even standing on the limber, while the gun is kept back behind the crest of a hill so as to be concealed from view.

In the French pedestal sight no telescope is used, but the sight is directed on to the target by using the *collimateur*. This instrument consists of a block of clear glass about 2½ inches long by ½" square. The front face is blackened, except for a cross of clear glass (Fig. 31) while the rear face is ground like a lens. The effect of this is that when the eye is placed about a foot behind the sight, and in the optical axis of the lens, the layer sees before him a white cross on a black ground. The apparent distance of the cross is one metre, so that the *collimateur* gives a sighting radius equivalent to that of a rocking-bar one metre long. This is known as an *optical*, in contradistinction to a *real*, line of sight.



FRENCH PEDESTAL SIGHT.
FIG. 30.

To use the collimateur, the layer keeps his eye about a foot behind the eye-piece, looks alternately at the object and the cross, and works his elevating and traversing wheels till he brings first the horizontal line and then the vertical line to coincide with the object.

The collimateur is rarely used for laying for elevation. As a rule the gun is layed for elevation by clinometer, and for line by a conspicuous auxiliary mark. The relative direction of the mark is measured by the battery commander with a telescope mounted on a graduated stand.

The necessarily small scale of the pedestal sight entails small graduations, leading to errors in setting.

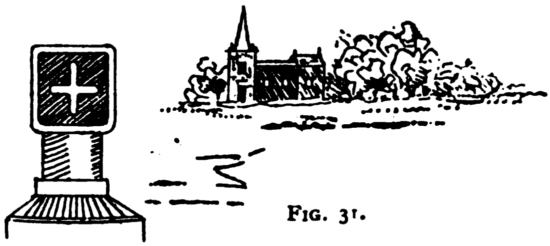
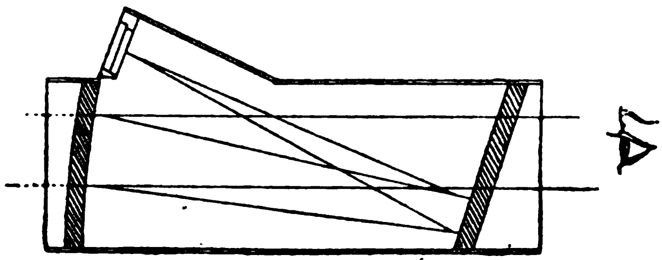


FIG. 31.

The Ghost Sight. (FIG. 32.)

Suppose a rectangular box as in the diagram, closed in front and rear by glass plates. The lower half of the rear glass plate is silvered inside. An inclined tube is fixed into the top of the box; it is closed at the upper end by a ground glass plate with a cross cut upon it. A lens in the tube (not shown) throws the image of the cross upon the mirror surface of the rear glass plate, whence it is reflected to the



THE GHOST SIGHT.
FIG. 32.

front glass plate and thence back to the eye. The front glass plate is covered with a barely perceptible layer of some semi-transparent material, such as galena, which ensures the reflection of the image of the cross, while it allows the light from the target to pass in. The effect is that the layer sees the landscape before him with the image or ghost of a cross in the centre of the field. Since the cross appears to be at the same distance as the target, it is an easy matter for the layer to make cross and target coincide by working the hand-wheels.

From its compactness the ghost sight is well adapted to use as a pedestal sight. But it absorbs a good deal of light and is liable to derangement from dust getting on the mirror surfaces. It is usually fitted with a telescopic eye-piece.

To avoid the possibility of dust getting on the reflecting surfaces, the ghost sight is sometimes made of a single block of clear glass. This, however, absorbs more light than is desirable.

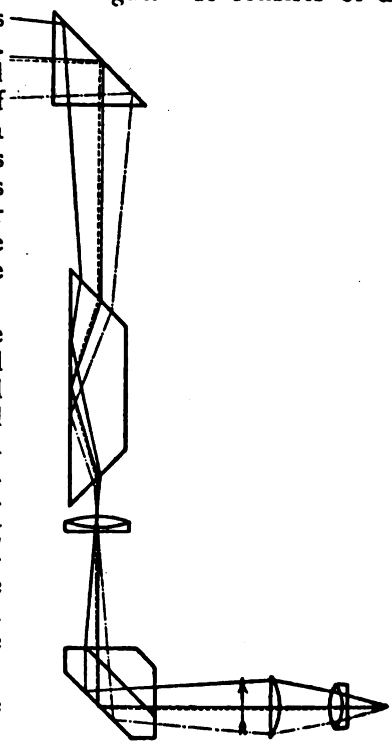
The Goerz Panorama Sight. (FIGS. 33 & 34.)

Supposing it were possible to point the object-glass of a telescope in any direction without moving the eye-piece, this would afford a view in any desired direction without shifting the eye.

This is effected by the Goerz Panorama Sight. It consists of a short telescope bent at right angles and surmounted by a moveable head. The head is fixed on a horizontal graduated table and is capable of being turned in any direction by a tangent screw. The object-glass is in the vertical tube and the light is reflected to the eye by two prisms or mirrors inclined at 45°, one in the moveable head and one at the angle of the telescope.

These two prisms would not suffice to give an erect image, as if the head were turned round the image would appear more and more inclined, until at 180° it would appear inverted. A rectifying prism "R" as shown in the second figure is therefore introduced. This is connected by gearing with the moveable head so as to revolve with it, but at only half the rate of angular revolution. This gives an erect image in whatever direction the head is turned.

The magnifying power is 4, the field 10°.



THE GOERZ PANORAMA SIGHT.

FIG. 33.

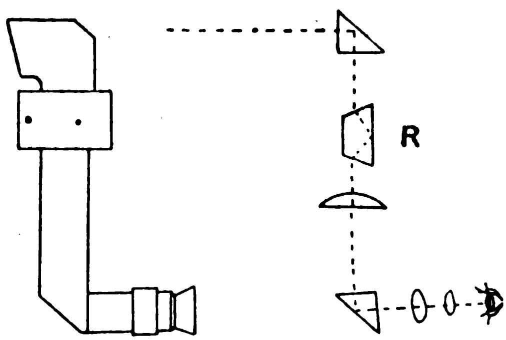


FIG. 34.

The sight may be mounted either on an arc, a rocking bar, or a pedestal. It serves both as an ordinary telescopic sight and as a dial sight for laying at an auxiliary mark. It has the advantage of enabling the layer to see over the top of the gun-shield without exposing himself, and of giving a high line of sight, enabling the gun to be kept well back under cover. It is liable to the objection common to all prismatic optical appliances, that it is put out of action by dust on the faces of the prisms.

Page 90.—The Goerz panorama sight has now been adopted for field guns and howitzers by all the principal nations of the world, except France, which adheres to the *collimateur*, and Spain, which has introduced the Zeiss zig-zag sight. Germany has the panorama sight for the field howitzer, but has as yet only the laying plane for the field gun. For use with balloon guns, the panorama telescope is turned over on its side, so that the moveable head traverses in a vertical instead of in a horizontal plane.

The Zeiss Zig-zag Sight.

This has lately appeared as a rival of the panorama sight. It enables the layer to lay all round the circle without shifting his position or moving his head more than a few inches. It consists of a short straight telescope which can be traversed so that it commands the angles from 60° right to 60° left. A reflecting prism can be folded down in front of the object glass, and turned either to right or left. This prism reflects the light through an angle of 120°, so that when turned to the right of the object glass the telescope commands the angles from 60° to 180° right—that is, to the right rear—and when turned to the left it commands the angles to the left rear. Thus the telescope commands the whole circle, with a traverse of only 60° to either side. As a matter of fact it traverses 65 degrees, and gives an overlap of about 10 degrees, including the field of the telescope, when changing from one position of the prism to another. The motion of turning the prism into position covers up the original index arrow and exposes a fresh one corresponding to the altered reading of the scale, so that the layer does not have to add or subtract 120 degrees when he shifts the prism.

This sight is simpler and more compact than the panorama sight. It is subject to the disadvantage that the layer's head is on a level with the object glass, and is not covered by the shield as in the Goerz instrument.

THE INDEPENDENT LINE OF SIGHT.

This device for quick and easy laying was first brought out by the French in their Q.F. field equipment. It is now used by the leading French and English makers, but has not found favour in Germany for field guns, although both Krupp and Ehrhardt have brought out carriages with sights of this type.

The theory of the invention is as follows :—(Fig. 35.)

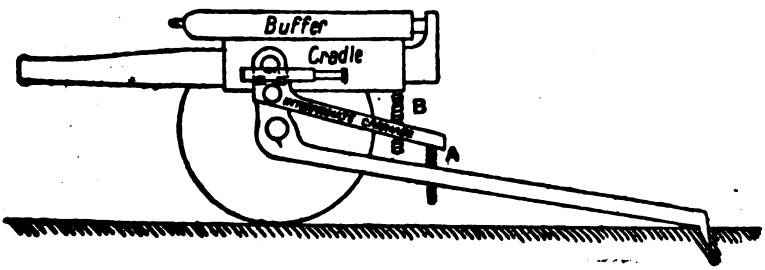


FIG. 35.

Let the gun in its cradle be mounted on an intermediate carriage, elevated and depressed by the screw "A." The telescopic or ordinary sight is fixed to this intermediate carriage. The gun and cradle are elevated and depressed by the screw "B."

To lay the gun, the layer works the laying screw "A" until the telescope points at the target; the gun also, if no elevation has been put on, is then pointing straight at the target. To give the gun the elevation necessary for the range, the elevating number on the right

of the gun now works the elevating screw "B" till the gun is sufficiently elevated, the amount given being shown in yards on a drum fixed to the cradle, and connected by gearing with the intermediate carriage, so that it records the angular movement of the gun with respect to the intermediate carriage.

This motion given to the gun does not disturb the intermediate carriage with the telescope attached to it, and the telescope still remains layed on the target.

Once the sights are layed on the target, the elevation of the gun may be changed in a moment by a turn of the elevating wheel, without disturbing the laying. The layer does not have to concern himself about the elevation; he has only to keep his sights on the target while the other numbers continue the service of the gun.

This device is especially valuable when firing at moving objects, when the range and the laying have to be altered simultaneously.

The same result may also be obtained by other mechanical devices without the use of the intermediate carriage. Suppose a long elevating screw, with the sight connected to its centre, the lower end passing through a nut at the side of the trail, the upper end through a nut at the side of the cradle. Then if the lower nut be turned by the laying wheel, the screw, the sight and the gun will go up or down together; if the upper nut be turned by the elevating wheel, the gun will go up or down the screw without moving the sights.

Scott's Automatic Independent Line of Sight.

Since the introduction of the shrapnel-proof shielded gun it has become important to obtain direct hits on it with percussion shell. This requires great accuracy of direction. Now it has already been shown that if one wheel of the gun is higher than the other, this causes the shell to deviate to the side of the lower wheel. And if we have six guns all with their wheels at different levels, and these varying from round to round, "pin-point" shooting becomes impossible, unless the guns are fitted with reciprocating sights. Now these must be attached to the cradle in order that the longitudinal pivot may be parallel to the axis of the gun at all elevations. With the ordinary form of independent line of sight, in which the sight is fixed to the intermediate carriage or its equivalent, the pivot cannot always be parallel to the gun, and when the wheels are much out of level a serious degree of lateral error results.

In Colonel Scott's patent automatic sight the sight is fixed to the cradle, and is a true reciprocating sight. But since it is an essential feature of the independent line of sight that the sight shall not move when the gun is elevated, a special device has to be introduced to counteract the movement of the cradle. This is effected by supporting the sight on a cam connected to the intermediate carriage. Suppose the sight layed on the target, and the gun then elevated 10 degrees, the cradle, with the sight attached, will be pointing 10 degrees above the target. But at the same time the revolution of the cradle trunnion in its bearing on the intermediate carriage will actuate the cam, and will depress the telescope through 10 degrees, so that it

will still be pointing at the target. This device is readily applicable to any form of sight, whether arc sight, rocking bar, or pedestal. Suppose, for instance, the rear end of the rocking bar supported on a spiral or "snail" cam, pivoted on the cradle; then if a circular portion of this cam be made to gear into a toothed arc fixed to the intermediate carriage concentrically with the cradle trunnion, then when the gun is elevated the cam will revolve and will raise the rear of the bar, so that it will remain directed on the target.

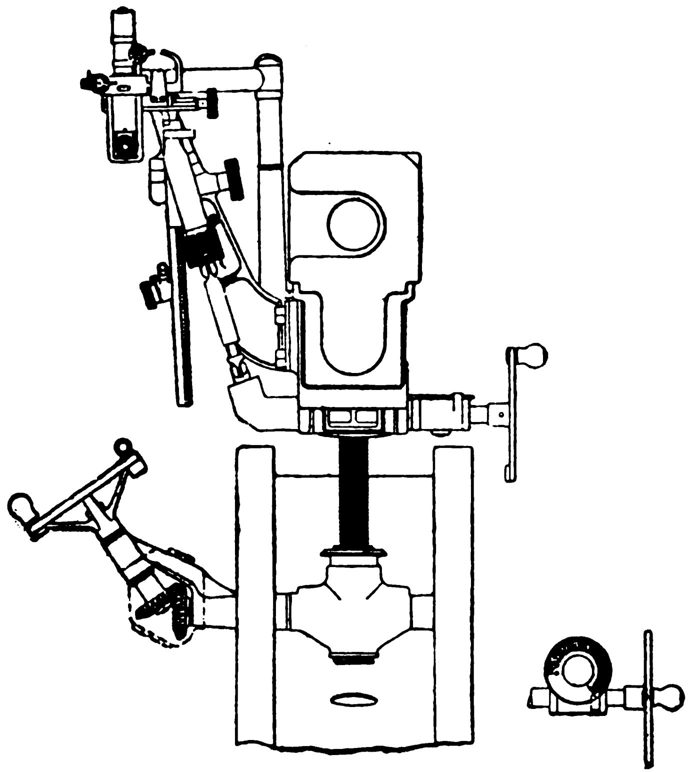


FIG. 36.

Krupp's Independent Line of Sight.

More recently, Messrs. Krupp have introduced a device on the same principle as Colonel Scott's.

In Fig. 36, which shows the Krupp gear, the arc sight, carrying a panorama telescope, is pivoted, so as to reciprocate correctly, on a bracket attached to the breech end of the cradle. The outer telescopic screw (the end of which is just visible in the figure above the socket) is turned by the laying wheel on the left, and elevates the gun and sight together, so as to enable the sight to be directed on the target. The inner telescopic screw is turned by the elevating wheel on the right, and elevates the gun while at the same time it depresses the sight to the same extent, so that the sights remain steady on the target. For the elevating wheel is connected to the sight by the connecting spindle shown in the figure so that as the gun is screwed up the sight is screwed down, and remains in the same place,

The connecting spindle is telescopic and has two universal joints, which enables the sight to be revolved about a pivot parallel to the axis of the gun in order to cross-level it.

The Krupp Triple Elevating Screw.

In another Krupp design there are three telescopic elevating screws, one within another. The rear end of the rocking-bar sight is supported by a connecting-rod attached to the second screw of the three, which does not revolve. This arrangement is mechanically equivalent to our double-ended screw, the outermost and innermost screws, each turned by its own wheel, replacing the nuts on the carriage and on the cradle. The Krupp arrangement has the advantage in that it is set centrally under the breech instead of at one side. This gear does not allow of the use of a reciprocating sight.

CLINOMETERS.

A clinometer is usually a spirit-level mounted in a frame so as to be capable of any desired amount of inclination to the horizontal plane.

In the Watkin clinometer the level is mounted on trunnions at one end, the height of the other end being controlled by a drum working on a screw. This drum is graduated helically in degrees and minutes.

This form of clinometer is now-a-days being superseded by the simpler *arc clinometer*.

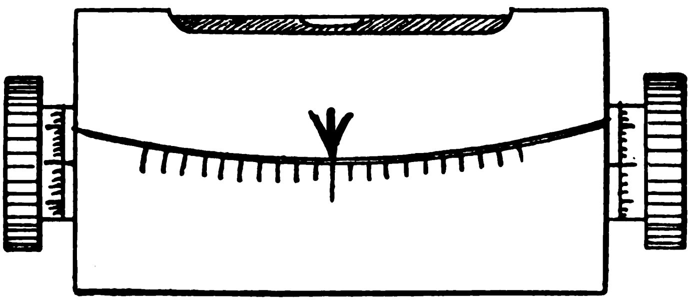


FIG. 37.

The upper block which carries the level, and the lower block, which is flat at the bottom, are capable of sliding on one another, the surfaces in contact being circular curves, The upper block is traversed by a tangent screw with micrometer head divided into minutes; the degrees are marked on the face.

It is immaterial whether the circular arc is fitted vertically or horizontally. In the arc sight already described the level is simply fixed to the head of the arc and the necessary inclination is given to the level by raising or lowing the arc through the requisite number of degrees. In this case the arc is so large as to afford plenty of room for small sub-divisions, and a micrometer screw becomes unnecessary. In the latest equipments the clinometer is fixed to the side of the arc, low down, so that the layer can see the bubble without rising from his seat.

The Battery Director.

Under the heading of sighting appliances we may also class the battery director and the plotter.

The director consists of a small telescope, or sighted ruler, mounted upon a tripod stand. On top of the stand is fixed the base plate,

graduated in degrees from 0 to 180, right and left. On the base plate is pivoted the upper plate, carrying the index arrow, and on this again is pivoted the socket which carries the telescope or ruler. The upper plate can be clamped to the base plate, or the socket to the upper plate, when desired. This appliance enables the battery commander to measure horizontal angles. The method of using it is explained in Part III.

It is a vexed question whether the director and dial sight should be graduated right and left, as in our own service, or continuously round the circle. The latter system involves the use of higher numbers, which are not convenient for signalling, but avoids the possible confusion due to the terms "right" and "left." In most foreign sights and directors the circle is graduated in *mils*, or thousandths of the range.

Besides its use for measuring horizontal angles, the director can also be used for measuring vertical angles such as the angle of sight. For this purpose the telescope socket is pivoted horizontally, and a small clinometer is attached to it. This clinometer is also used for levelling the base-plate when horizontal angles are required to be measured accurately.

The Field Plotter.

This instrument is invaluable in indirect laying. It enables the battery commander, from a distant observing station, to determine the horizontal angle, with reference to a given aiming point, at which a gun must be layed to strike a target invisible from the battery, and also to determine the range from gun to target. Its use in conjunction with the range-finder is described in Part III. The present form of the instrument is due to Colonel Guthrie-Smith, R.F.A. It consists of two arms graduated in yards, each pivoted on a semi-circular arc divided into degrees. The pivots can be set at any required distance by a slide also graduated in yards.

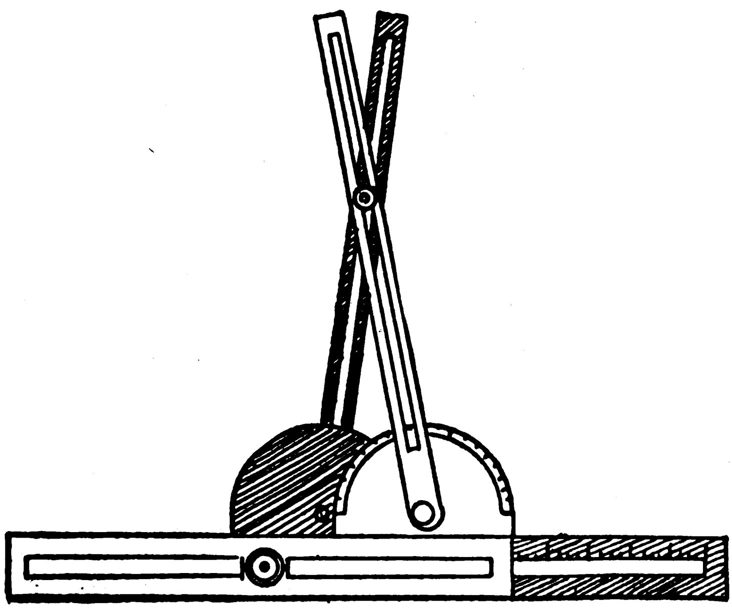


FIG. 38.

In principle the plotter is an instrument for solving a triangle, having given two sides and the included angle. The distance from the observing station to the gun is set off on the sliding base-bar, and one arm set and clamped to the angle between the gun and the target, as measured from the observing station with the director. The pivoted clamp is then slid along the arm to the graduation corresponding to the distance from the observing station to the target. On turning over the instrument, the graduation at which the second arm stands gives the angle at the gun between the observing position and the target, and that at which the pivoted clamp stands gives the range from gun to target. Since all the figures referring to the data are on one side of the instrument, and all those referring to the solution on the other, it is practically impossible to make a mistake in reading it.

Combined Plotter and Director.

It has frequently been proposed to set the plotter on a stand, and to make it fulfil the functions of both plotter and director. An instrument on this principle, devised by Captain Baumann, is in use in the Austrian army. The combined instrument has several theoretical advantages. Instead of measuring angles, the base-bar is directed at the battery, and one arm at the target; the gun angle and the gun range can then be read off on the other arm.

The Baumann plotter, and others of the same type, have another important property, in that the gun angle of sight can be determined from a distant station. Let the battery be called B, the target T, and the observing station O, and let the three points T O B be at different levels. Then by aligning the base-bar on the battery and one arm on the target the plotter is brought into the plane of these three points; the two arms and the base-bar form a triangle similar to the triangle T O B, and in the same plane, and the second arm of the plotter is parallel to the line BT. Therefore by applying a clinometer to the second arm we can measure the inclination to the horizontal of the line BT, that is, the gun angle of sight.

The practical objection to combining the director and plotter is that if the plotter is made of the ordinary size, with open graduations, it is a clumsy instrument to use on top of a tripod; while if made smaller it requires a vernier on each scale. What is required is an instrument which, when set, will not only perform the calculations automatically, but will show the three results—the gun angle, the gun range, and the gun angle of sight—appearing in figures through holes in a dial.

The gun angle of sight can be found with the ordinary director, if the base plate be set so that it is in the plane of the three points TOB. If the telescope be then set to the gun angle, TBO, as determined by the plotter, it will be parallel to the side TB, and its inclination to the horizontal can be read on the clinometer attached to it.

Rangefinding with the Director.

The French and German director telescopes have graticules in the field. By turning the telescope, the graticule can be set either horizontally or vertically. If the angle subtended by an object of known diameter or height (such as a gun wheel, a picket, or the rangetaker's cord) be observed, this gives the range from the director to the object. This method is most useful for measuring short distances, such as the base from the director to the gun. The same object can be achieved without a graticule, by measuring the angle subtended by a sub-base on the graduated base-plate. To give accurate results, the length of the sub-base should, in this case, be not less than 10 per cent of the base.

CHAPTER XII.

BREECH ACTIONS.

Three principal methods of closing the breech are in use in England and on the Continent, namely :—

The interrupted screw, otherwise called the swinging block.

The wedge.

The eccentric screw.

The Interrupted Screw.

If we take a screw fitting into a nut, and cut away the threads of the screw all down the right side, and the threads of the nut all down the left side, then the screw may be pushed straight into the nut. And if the screw be now given half a turn, the remaining threads will engage with the remaining threads of the nut, and the screw will be firmly held.

This would be a lop-sided arrangement, so in practice the breech screw is cut away for every alternate quarter of the circumference, and the nut—that is, the screwed breech of the gun—is cut away to match. Only one quarter of a turn is then required to lock the screw.

The breech screw is supported by a frame called the carrier, pivoted to the breech of the gun at one side.

The Conical Breech-screw.

If the breech-screw be cylindrical, then, unless the arrangement described below is adopted, it must, after turning it to disengage it, be pulled straight out before it can be swung round on the carrier clear of the breech. But if it be made conical, it can be swung clear as soon as it is turned round. The only condition is that the surface of the cone must fall within a circle described from the hinge-pin of the carrier. This is known as a single-motion breech action. It is applied to guns with which metallic cartridge-cases are used.

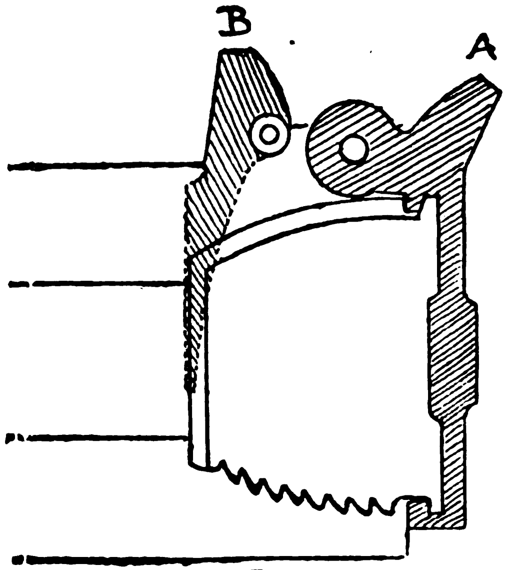


FIG. 39.

Fig. 39 gives a top view of the curved conical, or rather ogival, breech-screw used in the 15pr. Q.F. gun, the rotating gear and firing gear being omitted. The carrier and the extractor are shaded. The same action is shown in the Plate of the Ehrhardt ogival breech-screw. On pulling the lever seen at the top of the Plate, the effect is first to revolve the breech-screw till the plain part is opposite the threads in the gun, and then to swing it round to the right. On account of this swinging motion, breech actions of this type are known as *swinging block* actions. It will be noted that on throwing open the breech the projection A on the carrier strikes the tail, B, of the extractor, causing it to forcibly eject the empty cartridge-case.

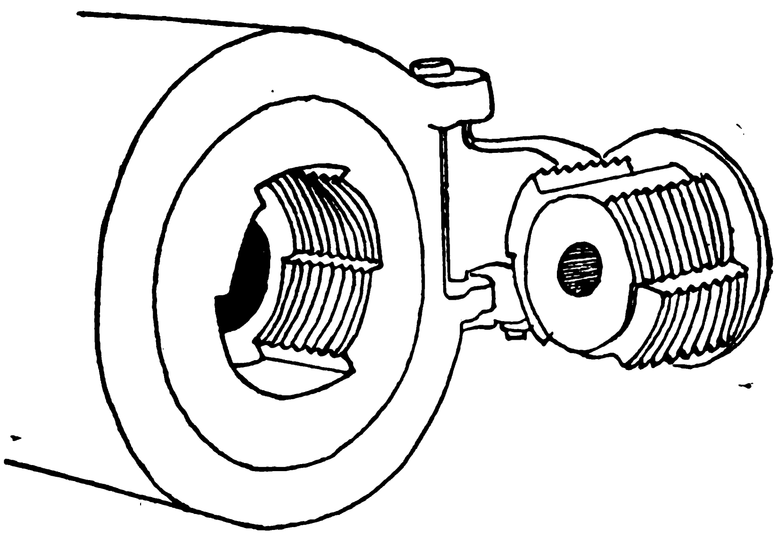


FIG. 40.

The Welin Screw.

This differs from the ordinary pattern in that the screw is stepped, giving an increased bearing surface. It will be observed that in Fig. 40, which represents a cylindrical Welin screw, only two of the six segments are plain, the others being threaded.

The Bethlehem Screw.

This is known as a "conical interrupted involute screw" and is developed from the Welin by running the steps into one another. It is a very strong form, and gives a locking surface extending over 240 degrees of the circle.

THE SINGLE-MOTION CYLINDRICAL BREECH-SCREW.

If the projecting screw threads are cut away at top and bottom to the form shown in the sketch, and if the hinge of the carrier is placed at some distance to one side, as at A A, then it is found possible to make a cylindrical breech-block which can be swung straight out without first withdrawing it by a straight pull. This is done by deepening the recess in the breech-piece at B so as to clear the corner of the block as it swings. By this method it is even found possible to produce a breech-screw coned in the reverse direction—that is, with the threaded portion of larger diameter at the fore end of the breech-screw than at the rear end. This form gives a great increase of strength.

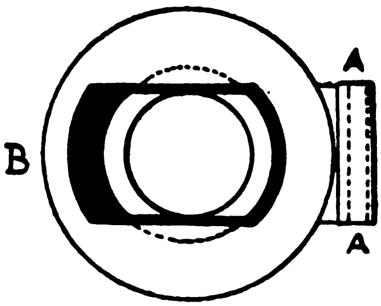


FIG. 41.

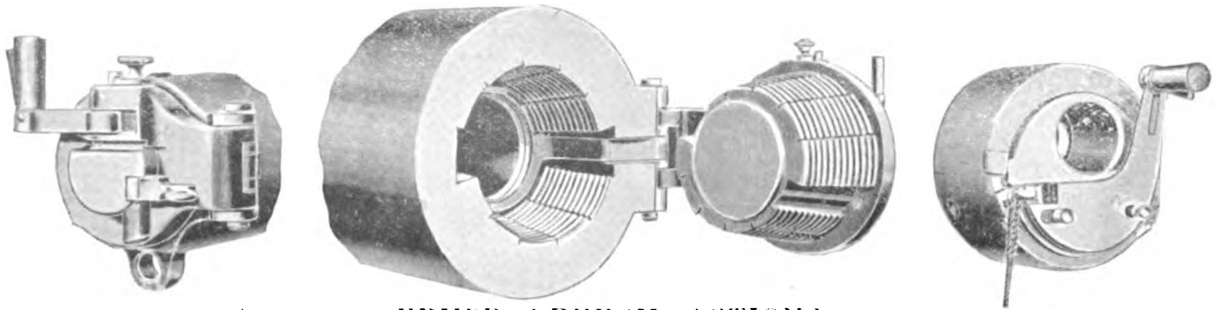
This action is more compact than the conical screw, and its only disadvantage is the extra metal required to strengthen the breech-piece to make up for the recess at B. It is used in our own Q.F. field equipment and in the American gun. A good example, made by Messrs. Krupp, is shown on the left of the Plate.

Pitch of Screw.

In the ogival screw described above, the block revolves in a plain circular recess in the carrier. This prevents the screw from advancing when it is turned to lock it, as the block has no end-play in the carrier. The screw is therefore made without any pitch, so that the screw threads are merely circular ribs. In other actions, such as our own, the recess in the carrier is threaded to the same pitch as the screw.

The Wedge.

A wedge of slight taper slides in a slot across the breech. There is a hole in the thinner end of the wedge, or rather, the thin end of the wedge is cut away semi-circularly, so that when it is pulled out the hole corresponds with the bore, and the shell and cartridge can be inserted. When the wedge is pushed home, the solid part of the wedge comes opposite the bore, and so closes the breech. This action is still a favourite in Germany. Its merits are strength and simplicity. A good example is the Krupp wedge seen in the Plate of the Krupp arc sight, and the Ehrhardt wedge in the Plate of the Ehrhardt actions. Note how the left of the breech is cut away to facilitate loading. The plate seen to the left of the breech is a guard to prevent the layer from getting his arm in the way of the recoiling gun.



KRUPP BREECH ACTIONS.

The details of the wedge mechanism are shown in Fig. 42, which represents an Ehrhardt action.

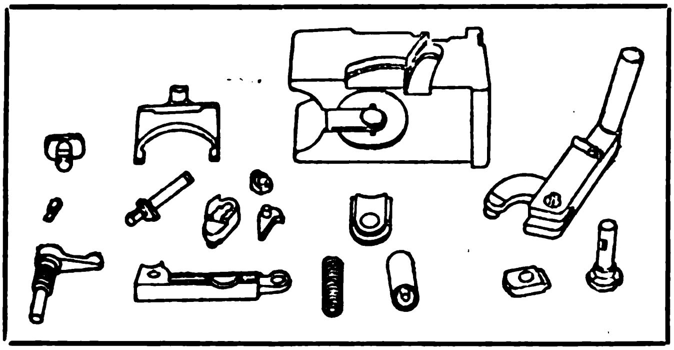


FIG. 42.

The lever, seen at the right of the figure, swings about a vertical pivot. The quadrant-shaped extension of the lever carries a roller which engages in the curved slot in the upper face of the wedge, so that as the handle of the lever is pulled from front to rear the wedge is traversed to the right. The forked extractor is shown on the left. It lies in a recess in the breech. As the wedge slides to the right, a tripper on its front face catches the projection on the extractor and presses it to the front, causing the extractor to rock on the curved surface of its shoulder so that its jaws are forced to the rear, ejecting the cartridge case.

The Eccentric Screw.

Suppose the breech-screw made larger than the gun, and having a hole bored down it at one side of the centre. Then if the screw be given half a turn, the hole will coincide with the bore; if it be turned back again, as in the figure, the solid part of the screw will come opposite the bore and so close the breech.

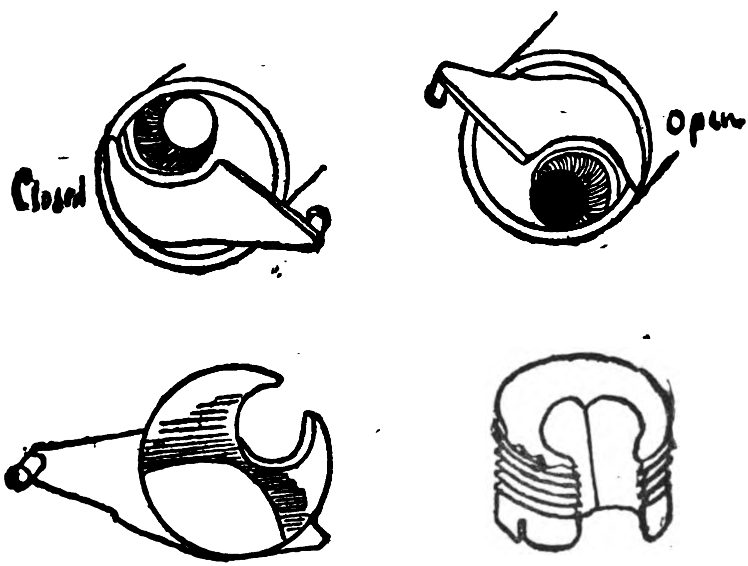


FIG. 42.

The eccentric screw is, in fact, a circular wedge.

This action is quick to manipulate, and, being all enclosed, is not liable to damage. It is therefore used in some Q.F. field guns, as in the French and Norwegian guns, and in the Elswick 1904 13-pounder. It is too heavy for large guns.

Falling Block.

In small natures of Q.F. guns, as in the Hotchkiss and Nordenfelt, the falling block is used. This is simply a wedge without any taper used vertically.

Obturation.

In all modern guns up to the 6-inch the escape of gas through the breech-closing gear is prevented by enclosing the powder in a solid-drawn metal cartridge case. This expands against the sides of the bore on firing and so seals the breech.

For heavy guns the weight of the cartridge-case becomes excessive, and an obturator is used. In England this consists of a pad of asbestos and grease fixed to the front of the breech-screw and covered by a mushroom head.

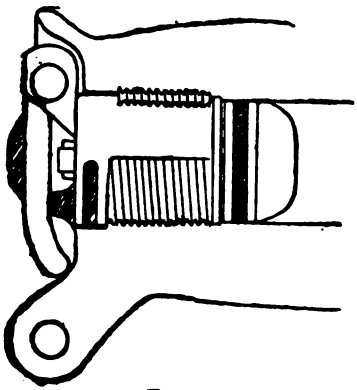


FIG. 44.

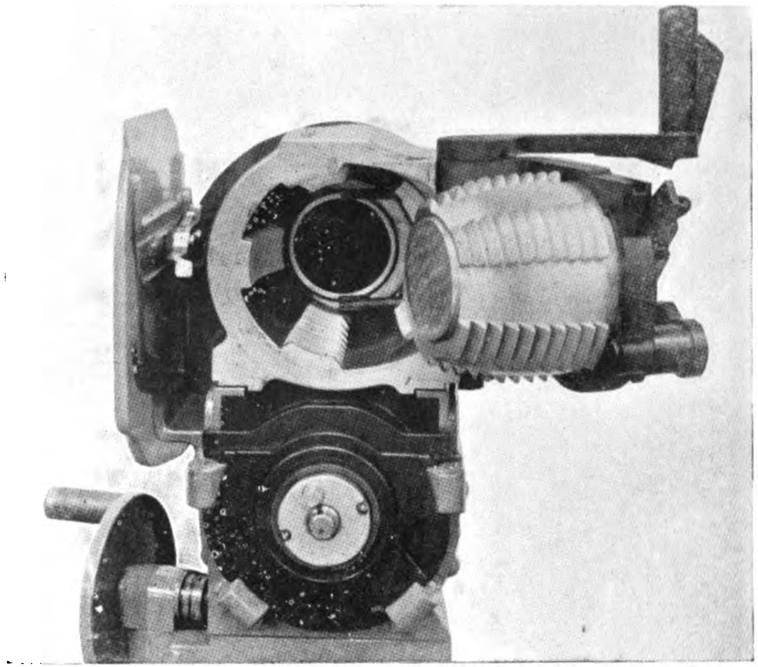
On discharge the soft pad is compressed and swells out so tightly against the surface of the bore as to prevent any gas from escaping past it. This system only works well with the cylindrical breech-screw, which is therefore used in all our heavy guns. With the wedge action, when intended for a bare charge, a soft copper ring is used on the solid part of the wedge, which is pressed tightly against the breech when the wedge is driven home.

AUTOMATIC SAFETY DEVICES.

All modern breech-actions have safety devices which prevent the gun from being fired till the breech is closed and locked.

The "safety" most commonly used is a bolt which locks the striker, and is not released till the end of the motion which locks the breech-block.

The swinging block fitted to the new American field gun has a novel safety device. The block is not set quite in line with the axis of the gun, but ¼ inch to one side. The striker is not in the centre of the block, but so as to be in line with the axis of the gun when the block has been rotated in the motion of locking. The effect of this double eccentricity is that when the breech is being closed the striker is not opposite to the cap in the cartridge, so that if the striker happens to stick or protrude no harm is done. The striker does not come opposite to the cap till the block has been revolved through a quarter of a circle to lock it.



SINGLE-MOTION OGIVAL BREECH SCREW.
EHRHARDT.

This action is known as the *eccentric block*, and must not be confounded with the *eccentric screw* described above.

FIRING GEAR.

All Q.F. field guns have percussion locks. These are usually "trip-locks" which do not require to be cocked; the pull of the firing lever first draws back the striker, compressing the mainspring, and then releases it. This action can be repeated in case of a miss-fire. There is some difference of opinion as to whether the layer or the elevating number should fire, but the former arrangement would appear to be best, since the layer is likely to lay more steadily if he knows that the gun cannot go off till he is ready for it.

In the Plate of the Ehrhardt wedge, the firing handle is seen hanging to the right of the breech. The firing number pulls this outwards, and as the gun recoils it is drawn out of his hand. The same firing action is used in the German gun. The details of the firing mechanism, lever, and extractor are shown in Fig. 42.

Semi-automatic breech mechanisms.

The principle of these is as follows:—In wedge and swinging block mechanisms the breech is opened and closed by the rotation of a spindle, actuated by the motion of a hand-lever fixed to it. In semi-automatic mechanisms this spindle is set parallel to the axis of the gun, and is extended forward to a length somewhat greater than that of the recoil stroke. A screw with a pitch of about one turn in 6 feet is formed on the spindle, which passes through a nut fixed to the cradle. During recoil the nut revolves freely; during the run-up the nut is held by a ratchet, and the spindle is rotated, throwing the breech open and ejecting the empty cartridge case. When the gun returns to the firing position the ratchet is thrown out of gear, and the breech would then be free to close under the pressure of a spring provided for this purpose, but that it is held in the open position by a catch connected with the extractor. When the next round of ammunition is inserted the extractor is pressed home, releasing the catch, and the breech closes under the action of the spring. An alternative method is to set the spindle in the usual vertical position, with a pinion on its lower end engaging with a rack formed on a rod attached to the gun and extending alongside the cradle. During recoil the rod is drawn back with the gun, and the pinion is not rotated; during the run-up the rod is held by a tripper on the cradle, the rack rotates the pinion, and the breech is thrown open. When the gun returns to the firing position the tripper is pressed down, freeing the rack, and the breech is held open by the catch as before. Several equivalent mechanical devices are used. In all semi-automatic gears the breech is made to open during the run-up, since if opened during recoil the cartridge case would be thrown out so violently as to endanger the men behind the gun. In the Krupp semi-automatic guns the breech-block is set vertically, so that the loading opening is at the top instead of the side of the breech. These guns are easily capable of firing thirty rounds per minute, as against twenty with non-automatic gear.

The Krupp automatic breech action.

This gear is intended primarily for anti-torpedo boat guns, but is also applicable to field guns It is a further development of the Krupp semi-automatic action. A magazine containing 8 cartridges is fixed to the cradle, so that it is above the breech when the gun is in the firing position. When the gun runs up, a cartridge rolls down into the breech and is pressed home by an upward projection on a chain rammer which works below the breech. When the cartridge reaches the extractor, and presses it forward, the breech closes and the gun is ready to fire. Or if the trigger of the pistol-grip be held back the gun will fire continuously. The Krupp automatic 12 pr., on field carriage, will fire 40 rounds a minute. But these high rates of fire cannot be continued for long, as the gun gets overheated. When this occurs, the first thing to happen, with any Q.F. gun, is that the oil on the guides burns, and the gun refuses to run up. If this did not occur the gun would get so hot as to explode the cartridge while being loaded.

RELATIVE MERITS OF DIFFERENT BREECH ACTIONS.

The strongest and simplest action is the wedge, which also lends itself to simple and efficient percussion firing gear, Next in order of simplicity comes the eccentric screw, which is however somewhat heavier than the wedge. The swinging block, when made as a single-motion action, is far more complicated than either of the above. It has however two advantages which more than make up for its defects.

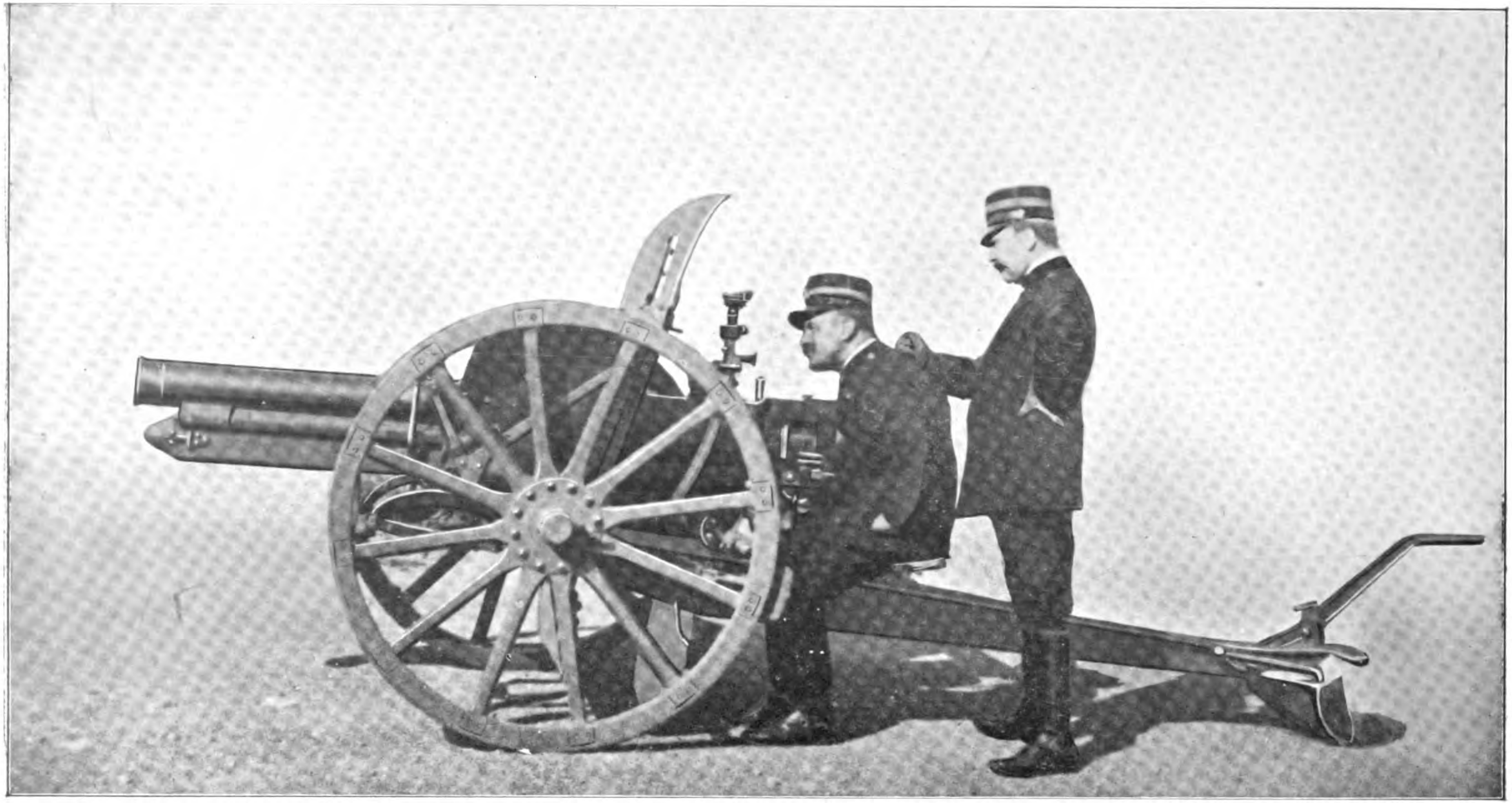
In the first place, it serves as a rammer to drive the cartridge home. Instead of the gunner having to push the cartridge right home into the breech—which is sometimes no easy matter when the chamber is foul—he has only to launch it in, when the swinging block, as it closes, completes the loading.

In the second place, the swinging block gives a far more powerful extractor than either of the other actions. With the eccentric screw the extractor is worked by a cam groove, with the wedge by a tripper on the front face of the wedge. But with the swinging block the "tail" of the extractor is made to project outside the gun, so that the block at the end of its backward swing strikes it like a hammer and forcibly ejects the cartridge case.

The provision of an efficient extractor is a matter of great importance, since in war-time numbers of hastily-manufactured cartridge cases would have to be used, which might not all be true to gauge. It is therefore desirable to have a powerful action capable of dealing with inferior ammunition without liability to jam.

The semi-automatic gear has the advantage of requiring one man less at the gun when firing. This is important with a mountain gun, where the amount of cover behind the shield is very limited. It is less important in a field gun, since six men (including the No. 1 and the ammunition numbers) have to be up in the firing line to handle the gun quickly.

The rate of fire afforded by the automatic gear would only be required on very rare occasions, and it is not worth while to carry about a mass of complicated mechanism to provide for such eventualities.



THE ITALIAN Q.F. GUN, 1905
KRUPP.

CHAPTER XIII.

PRINCIPLES OF CONSTRUCTION OF CARRIAGES.

The manufacturing details of carriage construction are beyond the scope of this book. The theoretical considerations on which the design of the carriage is based are, however, just as important from a gunnery point of view as those governing the design of the gun.

A gun-carriage is required to perform two principal duties—

First, to carry the gun and gun-shield across country without breaking down.

Secondly, to stand steady while the gun is being fired.

Considered as a travelling support for the gun, the carriage may be divided into three principal parts, the trail, axletree, and wheels.

The Trail.

The trail is merely a draw-bar, coupled to the limber by an eye-joint which allows of free lateral and twisting movement. It is this flexible connection which constitutes the difference between a gun-carriage and a four-wheeled carriage such as a G.S. wagon, and enables the former to travel easily over rough ground. The flexible connection has the disadvantage that the weight of the pole is not supported by the structure of the carriage, but must be borne by the horses. The portion of the weight carried by the horses varies according to the balance of the carriage, which is liable to be constantly disturbed by the movements of the men on the limber or by accidents of ground. For this reason a G.S. wagon travels better along the smooth surface of a road than a gun-carriage or an ammunition wagon.

Accordingly we find, in modern equipments, that all ammunition and stores except such as are required to be constantly present in the fighting-line with the guns are carried in G.S. wagons.

The Axletree.

This, in most modern guns, is a drawn steel tube tapered at the ends to receive the wheels. It presents no constructional features of interest.

In the Russian gun, and in many howitzer equipments, the axletree is not a tube but a forging, cranked downwards in the centre in order to reduce the height of the gun. These cranked axletrees are lightened by making the axletree arms hollow, but even so they are about twice as heavy as straight axletrees of the same strength.

The Wheels.

The design of the wheels is of the greatest importance to the mobility of the carriage.

In the first place, a wheel should be as large as possible, in order to travel easily over small irregularities. A six-inch wheel drawn over a piece of corrugated iron would drop into each corrugation and have to be pulled up each succeeding slope, while a 60-inch wheel would run over the tops of the corrugations without any perceptible drop between them.

Of still greater importance is the distance to which the small wheel sinks into the ground as compared with the large one. Suppose the ground is such that a pressure of 56 pounds on the square inch compresses it to a depth of 1 inch, and compare a 3 ft. and 5 ft. wheel, each 3" broad, under these conditions. Suppose the weight on each wheel to be 10 cwt., then each wheel will sink into the ground till the total resistance of the ground to crushing is equal to 10 cwt. Suppose this resistance to increase uniformly, which is practically the case for small depths; then in each case the amount

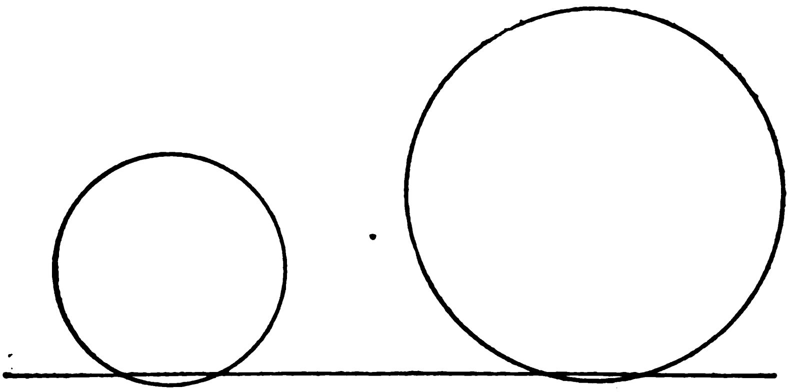
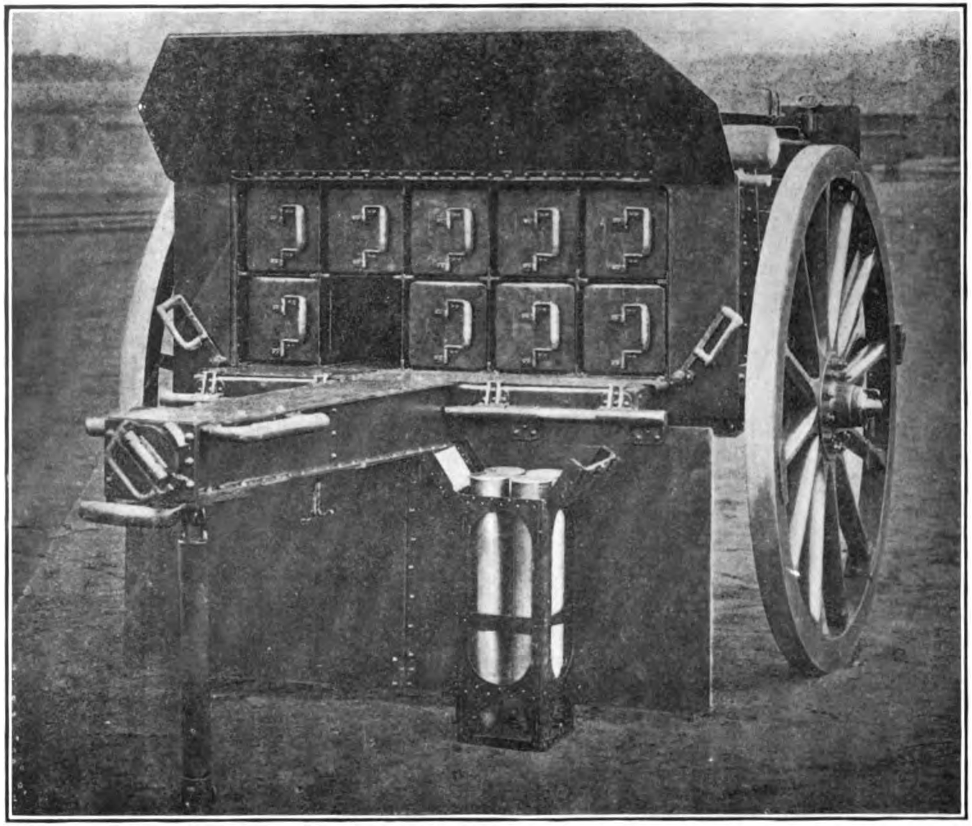


FIG. 45.

of the upward pressure of 10 cwt. will be represented by the area of the segment below the ground surface. In other words, the wheel may be considered as a transverse slice of a ship floating in water.

Let us assume that the "immersed section" of each wheel is 10 square inches, which is about the case with a gun-wheel on moderately soft turf, and let us compare a three-foot wheel with a five-foot one. With the assistance of the trigonometry book and table of log, sines we determine that the width of the immersed segment is 13" for the 3 ft. wheel and 15.5" for the 5 ft. one; the depths are 1.20" and 1.05" respectively. That is, the small wheel sinks only 0.15" deeper than the large one. This is a small matter so long as the wheel is at rest, But when it begins to advance the difference becomes a serious one.

Since the effect of the wheel in crushing the earth is represented by the area of the "immersed segment," and the area of a segment (or any other figure) of definite shape varies as the square of its dimensions, this is equivalent to stating that the work done by the



SKODA WAGON BODY.

wheel is proportional to the square of the depth of the rut. The effect of the work done by the horses is to make a rut 1.05″ deep for the large wheel as against 1.20″ for the small one. That is, the work is as (1.05^2) for the large wheel to (1.20^2) for the small one, or as 1.103 to 1.44. The difference is .337, or 30.6 per cent. of 1.105. That is, in this case the small wheel requires 30.6 per cent. more power to pull it than the large one.

It is hardly necessary to say that the above investigation does not give a complete account of the facts. For instance, the compression of the earth has been assumed to take place indefinitely slowly. Now we know from the theory of dynamics that more power is required to shift the particles of earth quickly than to do so slowly. Therefore the amount of power wasted by the small wheel increases as the speed increases. This is the reason why vehicles required to travel at speed have larger wheels than slow-moving ones, as in the case of a hansom and a four-wheeler.

Another fact which further handicaps the small wheel is that, from the sharper curve of the tire, it tends to throw up a wave of mud or soft earth in front of it, over which it has to travel.

From the point of view of the battery horse and his Major it therefore follows that the wheel should be as large as possible. In practice the diameter of the wheel is limited by the increase of its weight and of the weight of the extra long trail required to preserve the same trail-angle.

The diameter of the modern English gun wheel has been fixed at 4 feet 8 inches. Most foreign nations use 4 feet 4 inch wheels: these differ from the English pattern in that the spokes have no tongues, but are set in metal spoke-shoes fixed to the felloes. The Austrian pattern is an excellent one; it has 4 felloes connected by 4 spoke-shoes in which the feet of 4 of the spokes are set, thus supporting the joints of the felloes. The remaining 8 spokes have tongues.

Clearance.

In our own service we require a clearance of 18 inches between the ground and the lowest part of the limber or carriage when limbered up. The clearance is reduced by the use of a cranked axletree, and is only 13 inches in the Russian gun. This gives rise to difficulties when crossing rough ground.

It is not easy to secure sufficient clearance between the point of the spade, when limbered up, and the ground, and in foreign equipments with small wheels the position of the limber hook has had to be raised on this account.

Second Limber Hook.

The Bethlehem (U.S A.) Ordnance Works were the first to introduce a second limber hook, fixed at the back of the wagon body, and this has been adopted in the American Q.F. equipment. It is most useful in that it enables the gun and the wagon body to be taken into action together, if a horse in either team is shot, and it also enables the guns to be taken out of action without bringing up the gun limbers.

Detachments.

Besides the gun and ammunition, the men have to be carried into action. In most foreign equipments two men are carried on axletree seats, and either two or three on the limber. But the French in 1902 introduced the plan of carrying three numbers on the gun limber and three on the wagon limber, abolishing the axletree seats, and this has been imitated in our own Q.F. equipment. This plan would seem to be sound, since 3 men and the No. 1 are quite sufficient to work the gun for a short time when separated from its wagon, which will rarely be the case.

Weight on Wheels.

For ease of draught, it is found that the weight on the limber wheels should be less than that on the gun wheels in proportion of about 5 to 6. This is partly because the limber wheel has to travel over a rougher surface than that which it leaves for the gun wheel.

In designing for a given distribution of weight, the detachments are not taken into account. For it is considered that under war conditions of horse-flesh the men will have to walk for nine-tenths of the distance covered during a campaign.

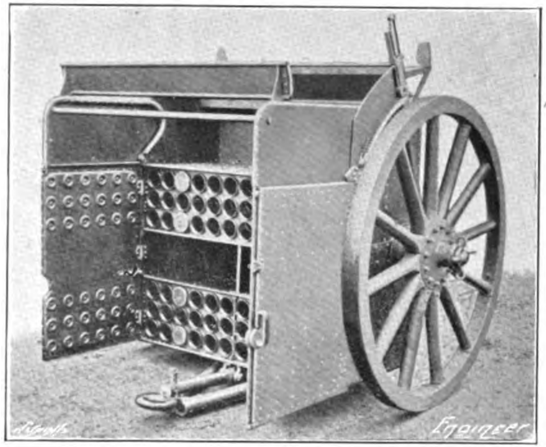
Balance.

A flexible limbered vehicle has to be carefully balanced to avoid straining and galling the horses, and to prevent the pole from flying about.

Having fixed the weight of the gun and limber, the next point to consider is the position of the limber hook, and the weight on the limber wheels. In heavy field equipments it is necessary, in order to distribute the weight, to carry the gun in a travelling position, several feet in the rear of the firing position, so that a large proportion of its weight comes on the limber wheels. But in ordinary field equipments this is not attempted. The weight of the trail on the limber hook must be sufficient to keep the trail steady, and not too much for the detachment to lift when limbering up. It is usually from 40 to 50 pounds.

The limber hook should be as close in to the axletree as possible. If it be far out, the jumping of the carriage as it passes over rough ground will exert considerable leverage on the limber, and will make the point of the pole fly up. On the other hand, the hook must project sufficiently to prevent the corner of the spade from jamming against the axletree when wheeling about. The hook must be high enough to give the necessary clearance between the ground and the point of the spade. In some equipments this necessitates cutting a hole in the rear door of the limber to allow it to open downwards to a horizontal position. In equipments in which the door is used as a hanging shield, a large hole has to be cut in it to clear the limber hook. An alternative method is to use two hanging doors, one on each side.

The weight at the point of the pole should be sufficient to keep it steady, without putting too much weight on the horses' necks. The present tendency is to reduce this weight, and about 10 lbs is considered quite sufficient. In the German gun there is no weight at the point of the pole when in draught.



EHRHARDT WAGON BODY.

The seats for the detachment on the limber, and the position and slope of the footboard, should if possible be so adjusted that the weight at the point of the pole is the same whether the gunners are mounted or dismounted. If it is found that the pole rises when the men are mounted, this can be rectified by extending the top of the limber box to the front, so that the men have to sit more forward. The correct height of the seat above the platform board for men of ordinary height is 16 inches. In some equipments (such as the Austrian) the limber box is considerably higher than this, and the correct height of the seat is obtained by fitting a flat store box on the platform board, the cover of which forms the footboard. In German equipments back-rests are fitted to the ammunition boxes on which the men sit. This however has two disadvantages; in the first place the high back makes the limber unduly conspicuous when the limbered-up wagon is unhooked beside the gun in action, and in the second place the men have to mount from the front, which is often inconvenient.

Ammunition.

Two methods of carrying ammunition are in use. In the German equipment the ammunition box is divided into compartments, each taking a basket with 3 rounds, or 2 rounds for field howitzers. In other equipments, such as the American, each round is contained in a separate tube of bronze or basket work fixed in the ammunition box. It is essential that the ammunition, when up at the gun, should be carried in a horizontal position to admit of quick handling. In the French and other equipments (detailed in Part IV) the wagon body is made like a tip-cart, so that it can be tilted into a vertical position beside the gun. This entails carrying the ammunition vertically when travelling.

It is generally considered that a limber should carry an amount equal to its own weight of ammunition and stores, and a wagon body 1½ times its own weight, besides the men.

Material of Limbers and Wagons.

Limbers and wagons are made entirely of steel, with the exception of the wheels and poles. Steel wheels have often been tried. A good pattern of doubled-spoked steel wheel is shown in the Plate of the Ehrhardt shielded gun (see Gun Shields.) They are stronger than wooden wheels of the same weight, but they are less elastic and cause more wear on the carriage in travelling. The best poles are made of hickory, which is superior to ash. Hollow steel poles are extensively used on the Continent; they are liable to double up if bruised or indented. Wooden footboards, as used in England, are more comfortable, but most foreign equipments have footboards of roughened steel.

Generally speaking, tubular steelwork for perches and similar purposes makes a strong and light construction, especially when supported by a core of compressed wood. The wood has to be soaked in a preservative such as mineral wax to prevent corrosion of the steel.

DRAUGHT.

For a gun and limber weighing, with detachment, 2 tons, running on 4' 8" service wheels, the draught may be approximately estimated as follows—

Hard dry macadam	80 lbs
Good but gravelly macadam ...	100 „
Unmetalled road, fair condition ...	150 „
Ditto, bad condition	200 „
Stiff muddy clay road	500 „
Sand road	700 „

The above figures represent the pull required to keep the carriage going at a walk. On a good hard road, the draught at a trot is but little greater than a walk; but on bad roads the draught is heavier at a trot. It may be noted that Messrs. Hancock & Gurney, road coach proprietors, found that their coaches ran better above four miles an hour than below that speed.

SPRINGS.

It is generally estimated that on ordinary roads the horse-power required to draw a carriage mounted on springs is only half that for a carriage without springs. The saving is greatest when the road is rough and gritty, so as to keep the springless vehicle in a constant state of jarring vibration. On deep heavy roads, springs make little difference.

Since nine-tenths of Artillery work on service is done on ordinary roads, it wouldtherefore be an advantage to mount guns, limbers, and wagons onsprings. This would enable the present six-horse team to be replaced by four-horse teams, keeping one pair spare for heavy roads. It is not improbable that we shall see this reform carried out before many years have passed—even if, by that time, the battery horse has been replaced by a motor-tractor. But, so far as the writer is aware, no attempt has yet been made to mount the gun-carriage on springs.

Several experimental equipments have been brought out, in which the ammunition boxes are supported on springs. But the Russian army, after its experience in Manchuria, has taken the lead in introducing a spring-supported equipment. The limber and wagon-boxes are carried on india-rubber block springs, and the limber-hook, pole, and draught loops are all set in india-rubber blocks. The Russians have certainly more experience, and more recent experience, than any other nation in marching artillery for long distances under war conditions, and their opinion in this matter is entitled to respect.

Spring Draught.

Before the general introduction of swingletree draught, spring draught-loops on the splinter-bar were used with great success, and were found to save collar-galls, especially on the wheelers. This purpose is now to a great extent served by the swingletree, and it is not usually thought worth while to incur the extra weight and complication of a spring attachment for the swingletree. This has however been adopted in some of the more recent Q.F. equipments, such as the Russian and the Spanish.

Spring Limber Hook.

A spring connection between gun and limber has often been advocated, and is actually used in some equipments of French design. The French contend that the extra weight of the spring attachment is more than compensated for by the weight which can be saved in the limber owing to reduction of travelling strains.

The general view hitherto taken of the matter by most Artillery authorities is that all these spring contrivances for reducing draught are unnecessary on good roads—since the draught is then well within the power of the team—and worse than useless on very bad roads, or across country. It has not been considered worth while to provide them for the sake of relieving the horses on indifferent roads.

Should a great Continental war break out, in which the guns have to traverse great distances, it is possible that the heavy expenditure of horseflesh may cause the above opinion to be modified, as has happened in Russia.

CHAPTER XIV.

THE GUN-RECOIL CARRIAGE.

General Principles.

A modern carriage is expected to stand steady on firing, so that in the first place it requires no running up, and in the second place it maintains the direction of the gun so that only a slight correction in elevation and direction is required after each round. The carriage is maintained in position by the spade, which sinks into the ground, and by the friction of the wheels upon the ground. If however the force of the recoiling gun were communicated directly to the anchored carriage, the effect would be to make it jump violently, which would not only disturb the laying but prevent the layer and elevating number from sitting on their seats. The hydraulic buffer is therefore interposed between gun and carriage. If the gun were rigidly attached to the carriage, the latter would be forced back perhaps half an inch at each round, and the whole of the recoil-energy would have to be absorbed in that half inch of motion. Instead of this, the gun alone is allowed to recoil through four feet or so, and though the recoil-energy is in this case greater than it would be if gun and carriage recoiled together, yet it is so gradually communicated to the carriage that instead of a violent jerk we have a steady graduated pull, the only effect of which is to slightly compress the earth behind the spade

In a well-designed equipment, the amount of this pull is always less than that required to lift the wheels off the ground by tilting the carriage about the fulcrum, namely the spade.

The only motion of the carriage which takes place is therefore that due to the elastic bending and rebound of its parts under the cross strains set up on discharge. These strains are inevitable, since the direction of recoil cannot always be exactly in the line of the resistance of the earth behind the spade. One ideal form of carriage would be to have the trail hollow and the gun recoiling inside it; the elevation would then be given by raising and lowering the front of the carriage. Such a form is impossible if only because the layer would have to raise the whole weight of gun and carriage when giving elevation. Instead of this we have to be content with so adjusting the proportions of the carriage that at ordinary elevations the line of motion of the centre of gravity of the recoiling parts falls as nearly as practicable in the centre of the spade,

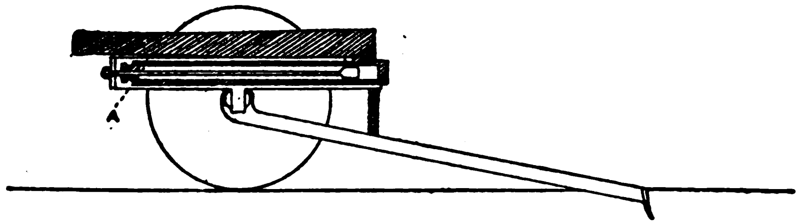


FIG. 46.

Action on recoil.

The above figure shows diagrammatically the arrangement of the original German Q.F. carriage, being taken from the Ehrhardt 1899 equipment. The buffer is made to recoil with the gun, because, as explained in the chapter on Recoil, the greater the weight of the recoiling parts the less the recoil-energy which has to be absorbed. The action which takes place on recoil may be thus briefly described:

The average velocity of the shell up the bore being $\frac{1640}{2}$ foot-seconds and the recoil-velocity imparted to the gun being 30 foot-seconds, then before the shell has left the muzzle the gun will have recoiled, roughly speaking, some 1½ inches. (It will really have recoiled for a less distance, since it does not attain its full recoil-velocity till after the shell has left the muzzle.) It is the behaviour of the gun during those first 1½ inches of recoil which affects the accuracy of the shooting. Now when the buffer-cylinder is drawn back from the piston the first thing that happens is that the air at A in the front of the buffer is compressed, so that for the first couple of inches the resistance to recoil is slight, and the gun moves back freely without feeling any resistance tending to alter its direction. When the air is fully compressed, the glycerine in the buffer begins to be forced past the piston through the grooves or *ports* in the walls of the buffer-cylinder, encountering a strong resistance in doing so. The amount of this resistance depends on the windage or difference of cross section between piston and cylinder, that is, on the area of the ports. By varying the depths of the ports at different points as required it is possible to adjust the resistance so as to be proportional to the stability throughout the whole recoil of the gun. The principles here involved have already been discussed in Chapter VII.

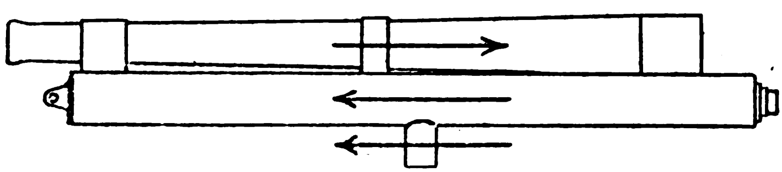


FIG. 47.

Cross Strains.

In an ideal equipment there would be two buffers, one on each side of the gun. This however would mean an increase of weight, and it would be difficult to balance the resistance in the two buffers, even if they communicated by a cross tube. At the present time all field guns are made with a single buffer.

Since the axis of the buffer must be at some distance from the axis of the gun, the resistance of the buffer is equal but not opposite to the force exerted by the gun; the two forces form a *couple*, as indicated by the arrows in the above figure, tending to revolve the gun clockwise, raising the muzzle and depressing the breech.

And again, in this particular form of carriage the connection between the buffer and the axletree, namely the vertical trunnion on the cradle, is not in line with the axis of the buffer, but some inches below it. Here we have another couple, also tending to raise the muzzle and depress the breech.

The fact that both these couples act in the same direction, tending to press on the head of the elevating screw and so bend the trail downwards, is in one sense an advantage. For owing to the preponderance the cradle presses firmly on the elevating screw, and owing to its weight the gun presses firmly on the cradle, hence there is no play or lost motion, and no risk of the downward pressure being converted into a blow.

On the other hand, the downward bending strain on the trail is undesirably heavy. For the whole system of gun, buffer, and cradle turns about the axletree, and the buffer is interposed between gun and axletree, rendering the distance between the gun and the pivot upon which it turns, unduly great. That is to say that the force of the recoiling gun acts at the end of a comparative long lever tending to break or bend the trail, which has to be made stiff and heavy in order to stand the strain.

Hence we find the tubular trail, once popular, being replaced, in equipments of this description, by trails of box or girder section. The tubular trail is strongest all round, but since the strength is principally required to resist a vertical bending strain it is found better to use a form giving more vertical and less lateral stiffness. In the Ehrhardt 1903 equipment, for instance, the original cylindrical trail is replaced by one of U section. But it is now found that the trail can be made stronger and lighter if made of the box or girder shape shown in the Plates of foreign guns.

We will now consider another type of carriage, illustrated in the annexed figure.

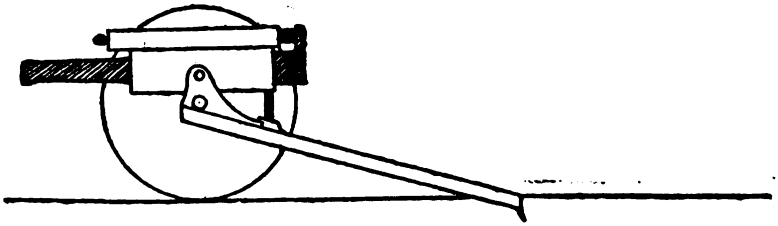


FIG. 48.

Top-buffer Carriages.

In this case the gun is between the buffer and the axletree. The recoil of the gun being resisted by the pull of the buffer, a *couple* is formed tending to raise the breech and depress the muzzle of the gun. On the other hand, since the buffer is attached to the top of

the cradle, the pull of the buffer tends to revolve the cradle (containing the gun) about its trunnions in the opposite direction, raising the muzzle and depressing the breech. Since the trunnions of the cradle are on a level with the axis of the gun, these two couples are equal, so that the only strain on the elevating screw should be that due to the weight of the gun when in the recoil position.

Effect of Wear.

One objection to the top-buffer system is the irregular action which takes place as soon as the bearing surfaces begin to wear. When the guide-ribs supporting the gun in the cradle, or the surfaces on which they rest, get worn, then the gun lies loosely in the cradle. Since it is held back from recoiling by the horn on the top of the breech attached to the buffer, the first motion of the gun on firing is to tip up, the breech jerking upwards and the muzzle down.

If there is also play at the trunnions of the cradle, the effect is here to jerk the muzzle upwards. Whether these two opposite actions take place simultaneously or no is a matter dependent on the friction between the surfaces, which is a variable quantity. Hence it is impossible to predict whether the upward or downward jerk will predominate. The actual displacement may only be a matter of hundredths of an inch, but this makes a good deal of difference at the target end of the range.

Attachment of Buffer.

It is found in practice that the point of attachment of the buffer the carriage has considerable effect on the steadiness. This point should be as low as possible, and should be in line with the prolongtion of the trail. This saves cross strains and bending strains and reduces the elastic rebound of the carriage.

Position of Buffer.

The buffer may be either above or below the gun. The former construction, which is adopted in England, enables the gun to be 6 inches lower on the carriage, and so reduces the overturning moment. On the other hand, the position of the attachment of the buffer to the carriage is unfavourable to steadiness, and the accuracy of the gun is liable to be affected by wear of the guides, as already pointed out.

The construction with buffer under the gun is used by all American and Continental gunmakers, who claim for it strength, simplicity, and a higher degree of steadiness than is attained by the English makers. Certainly the 1909 Krupp, Ehrhardt and Schneider guns, which have the buffer in a cradle under the gun, leave nothing to be desired on the score of steadiness in action.

Height of Wheels.

To give the greatest mechanical advantage in resisting the overturning pull of the buffer, the trail should be as long and the wheels as low as possible. The relative proportion of these two dimensions gives the *angle of the trail.*

In the French equipment, for instance, the wheels are 4 feet in in diameter and the trail 8 feet long on the ground line. The

proportion is therefore as 24″ (the height of the centre of the axletree) to 96″ (the length of the trail measured on the ground line.) This gives a trail angle of 1 in 4. Assuming that the French angle is correct, it will be seen that any increase in height of the wheel makes a four-fold increase in the length of the trail. Not only is this so, but the weight of the trail increases, not only in proportion to the extra length, but as the square of the length. For to maintain the same strength the long trail must be made stouter than the short one.

This is the reason why Continental manufacturers, who are obliged by the requirements of their customers to produce a perfectly steady gun weighing less than one ton, have cut the wheel down to the lowest possible dimensions.

Modern Requirements as Regards Steadiness.

On the Continent, steadiness is all the fashion now-a-days. That is to say that other and possibly more useful qualities are sacrificed in order to obtain such a degree of steadiness of the gun and carriage as will enable six or more rounds to be fired without its being necessary to re-lay the gun. Thus in the Swiss 1903 competitive trials one of the principal "events" was a series of 12 rounds fired without re-laying, and the success of the Krupp gun in this series was one of the chief reasons assigned by the committee for its selection as the Swiss Field Artillery weapon.

The French Field Artillery gun, which was the pioneer of all Q.F. field-guns, was and is perfectly steady in firing; but it weighs nearly 23 cwt. unlimbered, and its brake gear and recoil gear are decidedly cumbrous. In more recent guns the object of the makers has been to secure steadiness equal to that of the French gun combined with greater simplicity and less weight.

RECOIL GEAR.

The mechanism which absorbs the recoil of the gun is intimately connected with that which returns it to the firing position. It will therefore be convenient to consider the two together.

In the ordinary recoil-gear the recoil-energy of the gun (see Chapter on Recoil) is converted into heat, produced by the friction of liquid forced through narrow orifices. This heat is conducted away through the metal of the recoil gear, and is radiated into the air.

The recoil-gear consists of the cradle, the buffer, the check-buffer, and the running-up gear. It may also be held to include the spade, and, in some cases, the wheel-brakes.

The Cradle.

The cradle is that portion of the carriage in or upon which the gun slides in recoiling. In England we use a *ring cradle*, surrounding the gun, with the buffer and springs on top. All foreign armies use a cradle under the gun, containing the buffer and springs. This cradle may be box-shaped, as in the German equipment; of closed U shape, as in the Ehrhardt guns; or cylindrical, as in the Austrian gun. With a short cradle, such as that of the 18 pr., the guides upon which the gun slides are formed on the gun itself; with

a long cradle the guides are on top of the cradle, and guide blocks about 2 feet apart are formed on the gun. The means of elevating and traversing the cradle, and with it the gun, are described in Chapter XVI.

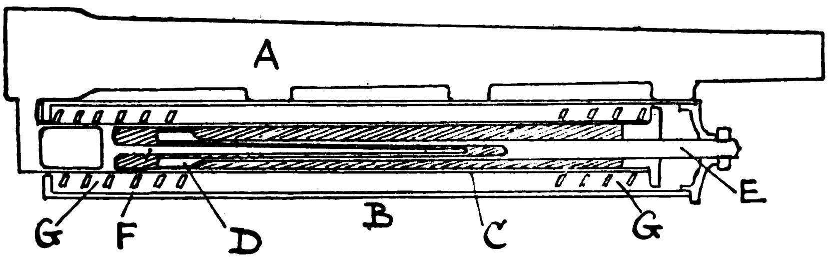


FIG. 49.

DIAGRAM OF CRADLE AND BUFFER.

A, gun; B, cradle; C, buffer; D, piston; E, piston rod; F, check buffer plunger; G, springs. The ports are not shown.

The Hydraulic Buffer.

This consists of a steel cylinder about 2.75" in external diameter, fixed to a horn projecting from the breech of the gun. In this cylinder works a piston; the piston rod passes through a gland at the front end of the cylinder, and is fixed to the front of the cradle. The cylinder is nearly filled with oil or glycerine. On recoil, the cylinder is drawn back with the gun, while the piston remains fixed, so that the liquid has to pass from one side of the piston to the other through the windage, or space between the piston and the walls of the cylinder. This passage of the liquid through the windage produces the friction necessary to stop the gun.

This frictional resistance must decrease gradually, as the centre of gravity of the recoiling gun comes further to the rear, reducing the stability of the carriage. (See Chapter VII.) In the earlier buffers this graduated resistance was obtained by varying the diameter of the cylinder at different points. This method is however only suited to small buffers with short and stiff piston rods as in the 15 pr. B.L. Mark II equipment. The next step was to make the piston a close fit, and to obtain the windage by cutting channels of varying depths, called *ports*, in the inner walls of the cylinder. These ports are open channels, like the grooves of an old-fashioned rifled gun, but are straight. They are usually about 0.4" broad and 0.05" deep, but the depth varies at different points, and the width is increased at the commencement of the recoil-stroke. This is the system now generally used. An alternative method is to make notches in the piston which are partly filled up by ribs of varying section projecting from the inner walls of the cylinder. (See illustration of the Rothe gear.)

In the Russian buffer, described below, the area through which the liquid escapes past the piston is regulated by a tapering plunger.

Yet another method, used in the controlled recoil equipments described in the next chapter, is to form the ports in the piston itself. These are partly closed by a disc valve which is rotated as the gun recoils by rifled grooves formed in the inside of the buffer.

In some equipments, for convenience of construction, the buffer is fixed to the cradle while the piston recoils with the gun. This is not a desirable form of recoil gear. For, as shown in the chapter on Recoil, the greater the weight of the recoiling parts the less the recoil-energy which has to be absorbed. And since the buffer and liquid together weigh about 85 lbs, this constitutes a substantial addition to the weight of the gun. The effective length of the buffer is about one inch greater than the length required to absorb the recoil-energy. The gun should never be allowed to recoil till the buffer comes "metal to metal."

Air-spacing.

On recoil the piston is drawn out of the buffer, causing a vacuum within. There is then a tendency to suck in air during firing. No air can get in during recoil, owing to the back pressure of the buffer-liquid against the gland; in fact the vacuum formed is at the other side of the piston. But during the beginning of the run-up, if the gland be not air-tight, a certain amount of air gets in. And though the gland may be oil-tight, it is not always possible to keep it air-tight, especially when the grease in the packing is frozen. If air gets in at every round, it will accumulate in the buffer in sufficient quantity to prevent the gun from fully running up. Thus the Russian equipment has an air valve through which the accumulated air can be let off.

It might be supposed that the air which enters would all be expelled in the recoil stroke. This is however not the case, because the air, during the run-up, gets mixed up with the liquid to a froth which does not escape through the gland.

For this reason it is desirable not to fill the buffer with liquid, but to allow from 5 to 10 per cent of air space. On recoil the air in this space expands and partly fills the vacuum. It also serves two other important purposes. If the buffer be completely filled with liquid, then at the commencement of recoil, in spite of enlarged ports, there is something approaching to a hydraulic blow, which causes vibration of the carriage and variable jump. This is avoided by air-spacing, as already explained under General Principles. Finally, it is necessary to leave a certain amount of air-space, because the buffer-liquid becomes exceedingly hot during rapid firing, and expands so that it would prevent the piston rod from going completely home unless an air-space were were provided to take up the increased volume of the liquid.

In howitzer equipments the question of air-spacing presents special difficulties, since the air all gets to the top of the buffer, under the gland.

Pneumatic attachment of Piston Rod.

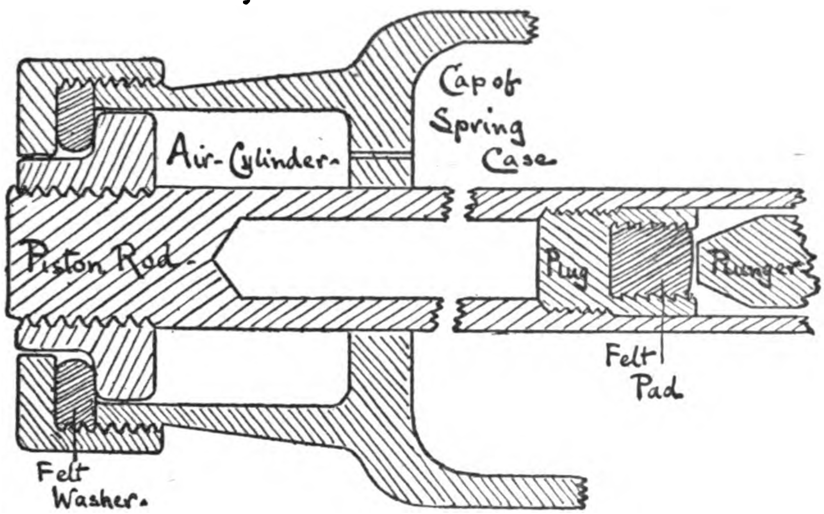


FIG. 49.

The objection to air-spacing is the irregular buffer resistance produced, according as the air is more or less thoroughly mixed with the buffer-liquid. The annexed diagram shows a device patented by the writer to overcome this difficulty. The intention is to obtain the principal advantage of air-spacing, namely a free recoil until the shell has left the bore, while leaving only sufficient air in the buffer to allow of the expansion of the liquid.

A small piston (Fig. 49) is formed on the end of the buffer piston rod, working in an air-cylinder on the front cap of the cradle or spring case. When the gun recoils, the buffer is drawn back with it, and the piston rod is also drawn back until the compression of the air in the air-cylinder balances the buffer-resistance, and the buffer-liquid begins to flow through the ports. But by this time the shell has escaped from the muzzle, and the subsequent vibration of the carriage due to the buffer-resistance does not affect its flight.

During the run-up, the pressure of the buffer-liquid on the rear face of the piston returns the piston rod to its original position. The device shown on the right of the figure is a felt pad against which the end of the check-buffer plunger presses to prevent the piston-rod from creeping back by its own weight if the gun is left elevated. In a howitzer it would be necessary to fit a strong spring for the same purpose. But if the piston were to creep back no harm would be done, except that the advantages of the device would be lost for the next round.

The pneumatic attachment might, instead, be fitted to the buffer-cylinder where inserted into the horn on the gun. This would give still greater initial freedom of recoil. Or, on the same principle, the piston might be made capable of longitudinal motion on the piston rod, and held back by a spring. The latter does not seem a practical arrangement, since the spring would have to be small and would probably break under a pressure of 1½ ton, and the buffer would have to be dismounted in order to obtain access to it.

The objection to the pneumatic attachment is that the first two inches of recoil, before the air-cushion is fully compressed, is nearly ineffective in stopping the gun, and consequently an extra two inches of recoil has to be provided for.

The Check Buffer.

When the gun is returned to the firing position by the springs afterwards described, it would run up with a jerk unless some means were provided of checking it. During the greater part of the run-up the gun is checked by the frictional resistance of the buffer-liquid as it returns past the piston through the ports. But at the end of the run-up, the piston is at the same point as at the beginning of recoil, and at this point the ports are enlarged so as to ease the recoil at its commencement, and they therefore offer little resistance to running up. Some additional resistance is required to bring the gun gently to a standstill. This is provided by the check-buffer shown in the diagram of the hydraulic buffer. The piston rod is made hollow, and a tapering plunger is fixed to the bottom of the buffer cylinder. As the gun runs up, the plunger enters the hollow, displacing the liquid therein. Owing to the taper of the plunger, the annular aperture through which the liquid has to escape decreases gradually in area, and the increasing resistance brings the gun to a standstill.

The Russian Buffer.

This buffer, which has also been adopted by Schneider of Creusôt, is described and illustrated in Part IV. The resistance is obtained by the use of a plunger on the same principle as in the check-buffer. There are no ports, and the piston is a close fit in the cylinder. Holes are cut in the piston rod close to the piston, through which the liquid escapes on recoil into the hollow piston rod and so to the other side of the piston. The hollow of the piston rod is partly filled up by a tapering plunger fixed to the bottom of the buffer-cylinder. The taper of the plunger is graduated so as to suitably vary the area of the annular space through which the liquid must escape past the plunger, and so regulates the resistance to recoil. A check buffer and a running-up valve are also fitted. The object of the latter appliance is described below.

The French Buffer.

This is described and illustrated in Part IV. It differs from all other buffers in that the liquid does not pass from one side of the piston to the other during recoil. Instead of this, it is forced through a narrow channel into a reservoir containing compressed air. On completion of the recoil, the compressed air drives the liquid back again, and so runs the gun up. In this system the resistance to recoil depends upon the fixed dimensions of the channel through which the liquid passes, and there is no means of regulating it.

The Pneumatic Buffer.

This is described and illustrated in Chapter XV. It contains compressed air in place of liquid, and the resistance is obtained by forcing the air through a system of narrow channels. In this, as in

the French gun, the buffer-piston also serves to run the gun up. The objection to the pneumatic buffer is the difficulty of keeping it tight.

The Running-Up Valve.

As we have seen, the resistance of the buffer towards the end of the run-up is insufficient to stop the gun. On the other hand, the resistance during the early part of the run-up is undesirably great, and, unless strong springs are fitted, the gun takes several seconds to return to the firing position. On this account most foreign buffers are fitted with a running-up valve in the piston, which allows the liquid to pass more freely during the run-up. This valve is pressed down by a spring, the strength of which is adjusted so as to give the required resistance to the passage of the liquid. In the Krupp buffers the opening of the valve is controlled by rifled grooves formed in the buffer-cylinder. This control enables the check-buffer to be dispensed with, since, with the comparatively weak running-up springs, the forward impetus of the gun is nearly absorbed by the time the piston reaches the enlarged portion of the buffer-ports.

The Running-Up Springs.

In the diagram of the hydraulic buffer it will be seen that the buffer-cylinder is surrounded by a column of helical springs. On recoil, these are compressed between the shoulder of the buffer and the rear plate of the cradle. When the gun has been brought to a standstill, the expansion of the springs returns the gun to the firing position.

Simple as this construction seems, great difficulties have had to be overcome to bring it to perfection. The first difficulty encountered was the crushing of the springs. Suppose the working length of the spring-column to be 6 feet, and the recoil 4 feet. Then in order to get enough initial compression to run the gun up at full elevation, and to overcome the resistance in the buffer, the column of springs, uncompressed, has to be about 8 feet long. That is, at every round 8 feet of spring have to be compressed into a length of 2 feet, which is severe treatment.

Various appliances were tried to reduce the stroke of the springs in proportion to the recoil-stroke. One device had a wire-rope attached at one end of the rear end of the cradle, and at the other to the gun, passing over a pulley on a moveable block in front of the springs. Thus when the gun recoiled 4 feet the springs were pressed back only half that distance.

The German makers got over the difficulty by the introduction of the running-up valve, which enables the strength of the springs to be reduced to a minimum. They use slender springs of flat section, made of very high-grade material (see *Steel)* which can be compressed metal to metal without permanent deformation. The springs are made in lengths of about 2 feet, separated by parting-plates. In some equipments (as the Russian) the lengths of spring are alternately right-handed and left-handed, to prevent the column from twisting when compressed.

Page 121.—Messrs. Krupp, in some of their later equipments, have reverted to the check-buffer, to avoid the complications of the revolving running-up valve. In their Dutch Colonial equipment they use both a check buffer and a spring-loaded valve in the piston.

The German makers' rule is that the initial compression of the springs should be from 60 to 70 per cent of the weight of the gun, and the final compression about double the initial compression.

It is considered that, after making all practical deductions, one pound of spring should be capable of repeatedly absorbing and giving out 40 foot-pounds of work.

Krupp Springs.

A good example of modern German practice is afforded by the Krupp arrangement of springs.

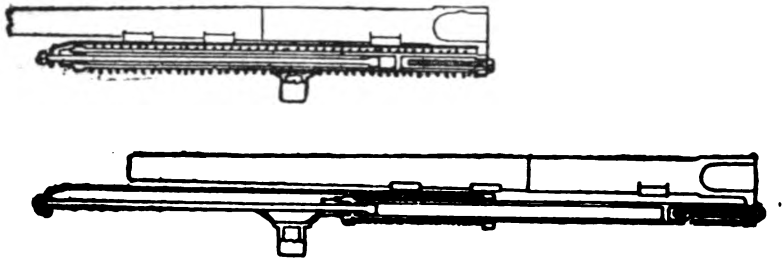


FIG. 50.

In this we have a single column of springs surrounding the buffer, and compressed between a collar on the front of the buffer and the rear plate of the cradle. There are three parting-plates, and the column of springs is compressed into a space between a third and a quarter of its length, so that its coils are almost touching. The spring is of wire, of flattened section, and has to be of excellent manufacture to stand this severe treatment. Messrs. Krupp are fully satisfied with the performance of this system, and have embodied in it all their new equipments, including those made for Italy and the Argentine Republic.

Note in the figure the vertical trunnion by which the cradle is attached to the lower carriage, also the method of lightening the cradle by cutting away portions of it, leaving the springs exposed.

The screw at the rear end of the buffer is for the purpose of putting the initial compression on the springs.

Telescopic Springs.

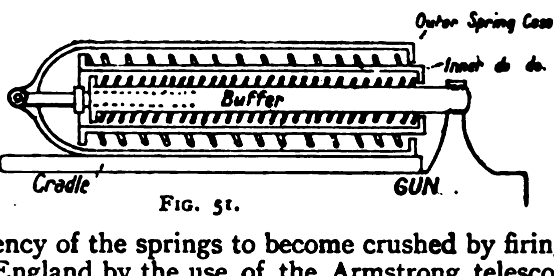


FIG. 51.

The tendency of the springs to become crushed by firing has been avoided in England by the use of the Armstrong telescopic spring-case, illustrated in the annexed diagrams. The outer spring is compressed between the shoulder on the outer spring-case and that on the inner spring-case; the inner spring between the shoulders on

Page 122.—Exposed running-up springs are no longer used.

the inner spring-case and on the buffer. Suppose that each spring is 5 feet long, and that the gun recoils 4 feet. Then on recoil the inner spring-case will be drawn out 2 feet, or until the compression of the inner springs balances that of the outer.

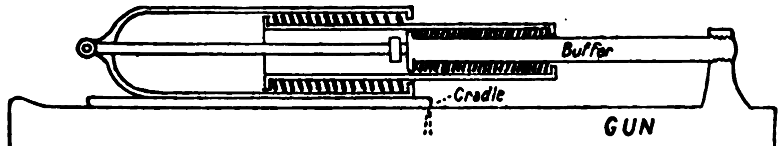


FIG. 52.

Thus each spring will be compressed only from 5 feet to 3 feet, or into $\frac{3}{5}$ of its working length. If a single 6-foot column of springs were used, without telescopic gear, a recoil of 4 feet would compress it into $\frac{1}{3}$ of its working length.

Several mechanical equivalents of the telescopic spring-case have been proposed.

Thus Messrs. Cockerill use a slide interposed between the gun and cradle. One spring, in ~~tension,~~ is between gun and slide, and the second set, in compression, between slide and cradle. On recoil the slide moves only half the distance that the gun moves, thus halving the strain on the springs.

Breakage of Springs.

Even the best springs, such as those made by Krupp and Ehrhardt, occasionally break during firing without apparent cause. This is not due to direct compression, since one of these springs might be pressed flat in a hydraulic press without breaking it. The breakage is ascribed to *waves of compression.*

Fig. 53.

When a gun begins begins to recoil, the spring, owing to its inertia, does not yield simultaneously throughout its whole length. The front coils are first sharply compressed, and then expand again, compressing the coils behind them. The result is that a wave of compression passes down the spring. When this wave reaches the rear end of the spring, which is supported by the rear plate of the cradle, it rebounds and returns up the spring, meeting a fresh wave which in the mean time has been started by the pressure of the recoiling gun. Now the effect of compressing a spring is to alter the inclination of its coils, that is, to bend the metal. And when two waves of compression meet, the result is to produce a shorter and more violent bend. Thus at sea, when waves from different directions meet, the long regular swell is broken into short and choppy seas. It is supposed, therefore, that the complicated bending stresses set up by the meeting (or possibly overtaking) waves are in some

cases such as to break the spring. In guns which recoil slowly, such as the 15 pr. Q.F., the pulsations during recoil are plainly perceptible when sitting on the layer's seat.

In running up, the reverse action takes place, except that the period of the pulsation is much longer, so that the gun often runs up in a series of visible jerks. This shows that the length of the wave (or rather of the dominant wave) is greater than that of the compressed spring-column.

When a spring breaks, it does not usually disable the gun, unless a broken end pierces the spring-case or indents the buffer. The broken ends of the spring screw themselves into one another, and the gun behaves much as before, except that the run-up is slow and feeble.

Internal Springs.

In some of the Armstrong equipments, and in the field guns of the Bethlehem Co., U.S.A., the springs are placed inside the buffer. It is claimed for this practice that working the springs in oil or glycerine deadens the vibrations referred to above, and reduces the liability to fracture. Also, in equipments in which the buffer recoils with the gun, the oil escapes past the piston at the rear or stationary end of the spring, and the oil remaining between the coils at the front or moving end presents these coils from being suddenly compressed metal to metal. The only objection to this system is that the buffer has to be large and heavy to contain a column of sufficient power.

Compressed Air Running-Up Gear.

The difficulties experienced with running-up springs led the French to take up the use of compressed air. It was first used in combination with the hydraulic buffer, as in the French gun already referred to. But about 1903 a simpler and more efficient gear was introduced by Messrs. Schneider of Creusôt.

In the Schneider gear the buffer-cylinder is of the ordinary pattern already described, and the running-up cylinder is entirely separate from it, and has a separate piston.

This construction, with hydraulic buffer and compressed air running-up cylinder, is known as the *hydro-pneumatic recoil gear.*

The running-up cylinder is filled with glycerine, which, on recoil, is forced into the compressed-air reservoir. When the hydraulic buffer has absorbed the recoil and stopped the gun, the compressed air forces the glycerine back into the running-up cylinder, drives the running-up piston out, and so runs the gun up. The glycerine soon mixes to a froth with the air in the reservoir, but this is immaterial, since the froth is not in the buffer, when it would produce irregular resistances, but only in the reservoir and running-up cylinder.

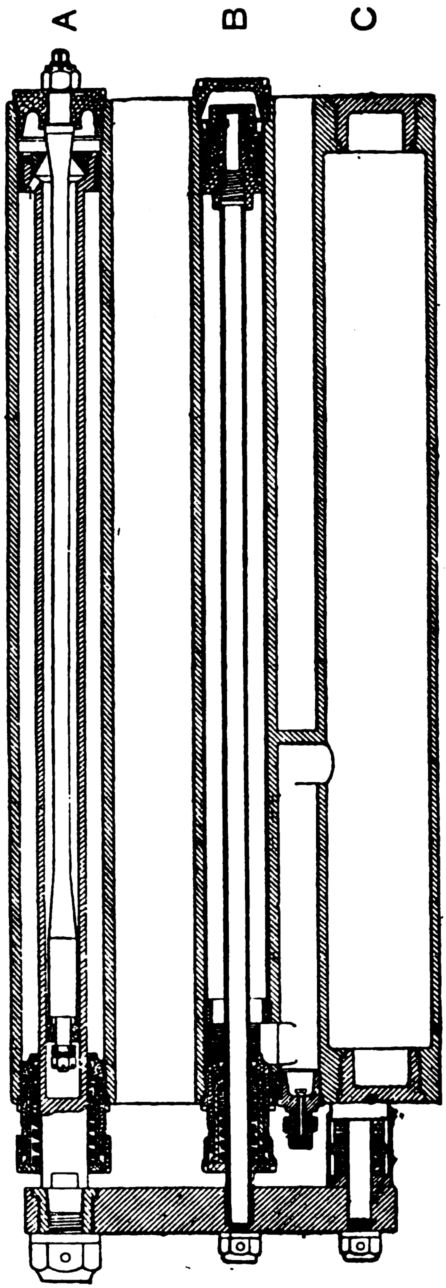


FIG. 54.
THE SCHNEIDER CANET H.P. RECOIL GEAR.

The Schneider gear as applied to field howitzers is shown in Fig. 54. The field gun pattern differs from it in that there are two smaller reservoir cylinders instead of one large one.

In the figure, A is the hydraulic buffer-cylinder, with piston, hollow piston-rod, and check-buffer plunger. The packing of the

gland is kept tight by a strong helical spring. B is the running-up cylinder, filled with glycerine, with packed piston. It communicates by the channel shown with the compressed air reservoir C, which contains air at a pressure of 180 lbs. to the square inch. The communicating passage is so placed that the gland of the running-up cylinder is always covered by liquid (or at least by the denser portion of the froth) whether in the firing or travelling position.

In the field howitzer, the 3 cylinders form part of the cradle, and do not recoil. (See Plate of Schneider howitzer in Part IV.) But in the field gun, the 4 cylinders (including the second reservoir-cylinder) are combined with one forging, which is fixed to the gun, thus materially increasing the recoiling weight and reducing the recoil-energy. The ends of these cylinders may be seen under the breech in the Plates of the Schneider guns.

In a later construction, Messrs. Schneider have replaced the plain buffer shown in the figure by a buffer of the type used with the Russian gun. They consider that this gives a more perfectly regulated resistance to recoil, and so enables them to reduce the weight of the carriage.

The behaviour of a Schneider hydro-pneumatic gun in action presents a marked contrast to that of a gun with running-up springs. There is no jumping or vibration; the motions of recoil and run-up are smooth and easy, and the gun appears to "go to sleep."

The objection to the hydro-pneumatic system, which has stood in the way of its general adoption, is the supposed liability of the compressed-air gear to leak under service conditions. It is one thing to keep packings tight in peace time, but this is another matter in war, especially if the guns have to stand out all night in a hard frost. This prejudice is now being gradually overcome. The Portuguese, for instance, have had the Schneider gun since 1904, and find it a very serviceable equipment. There is practically no loss of air, but there is a loss of glycerine in firing, at the rate of about one litre for every 2000 rounds. This is due to the film of glycerine adherent to the piston rod when it emerges, which is wiped off again when it re-enters the gland. The glycerine is easily replaced by pumping in a corresponding quantity with a pump resembling a bicycle pump.

The Spanish Schneider gun is now being tried on active service at Melilla, but no reports as to its behaviour have yet been received.

The French service gun has now been issued 12 years, and its recoil gear has given no trouble. One French battery was present at the relief of Pekin.

With the above exceptions, no hydro-pneumatic gun has been tried on active service; and none has been exposed to the trials of a winter campaign.

In the absence of direct evidence, it would appear that the hydro-pneumatic gun is likely to prove not less efficient than its rival under active service conditions.

The Brakes and Spade.

These may be considered as forming part of the recoil gear, although in some equipments the brake is not used when firing,

Page 126.—The Spanish Schneider gun did remarkably well at Melilla, and the Servian and Greek Schneider guns, with compressed air run-up, appear to have done well in the recent Balkan campaign. It is probable that compressed air running-up gear will be used in most future field equipments.

Ordinarily the brake is applied to the tyre, and consists of a brake-block, on a pivoted arm, applied to each wheel by a brake-screw. The two brake-arms are connected by tension-rods to a transverse bar pivoted under the breast of the carriage, so that if one tension-rod is shortened by the brake-screw both blocks are pulled on to the tyres.

In the American gun the brake-blocks are at the ends of a transverse bar as in our G.S. wagons, placed at the firing front of the wheels.

In the German gun, the Lemoine rope-brake is used. This is intended for travelling only. It is shown in the rear view of the German gun, Part IV. A flat braided wire rope, faced with leather, is attached to the brake-arm close to the brake-block. This rope takes one turn round a drum on the inner flange of the nave. When the loose end of the rope is tightened by a lever worked from the axletree seat, the wire rope grips on the drum, and the wheel as it revolves pulls the brake-block hard against the tire.

The French service gun has a brake which, in different positions, is used both for travelling and for firing. The gear consists of a pair of brake-blocks at the

Page 127.—Colonel Deport's "spike" is used instead of a spade in the French mountain gun. The point of the trail is nailed to the ground by a stout steel bar driven down by a hammer.

has a longitudinal fin which sinks into the ground, to prevent lateral movement of the carriage.

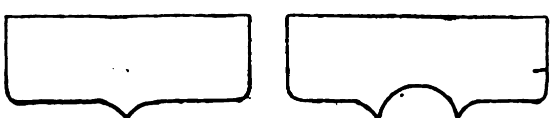
When the ordinary pattern of brake is applied to guns which traverse on the axle, the brake-blocks are made wider than usual, as shown in the Plates of the Schneider guns. The brake has then to be slacked off to traverse the gun. An alternative method is to attach the blocks to a transverse brake-bar fixed to the axletree so that it does not traverse with the carriage.

In some equipments, as in the 18 pr., the brake arms form the supports for the seats of the laying and loading numbers.

The Spade.

Guns which traverse on the axletree have a deep narrow spade, such as may be seen in the small sketch of the French gun in Part IV. Other guns have a wide spade with a sharp point which assists it to grip on hard ground.

The greater the depth of the spade, the greater the difficulty in getting sufficient elevation for the first round, before the spade has buried itself. This is especially the case on a forward slope. The point or long downward projection of the spade has, therefore, been reduced to the smallest dimensions, as at "A," and is sometimes duplicated at at "B." (Fig. 55.)



A FIG. 55. B

With a 9 foot trail, it is found that, in order to grip well, the point of the spade should be inclined to the rear at about 18 degrees to the vertical.

Various forms of spade are shown in the illustrations of the different guns described in Part IV. The Krupp form of spade with a horizontal plate in addition to the vertical one, as in the German gun, is the most favoured on the Continent, as this form does not tend to bury itself, On certain natures of ground, however, this form grips badly, as the pile of loose earth which forms under the horizontal plate tends to lift the spade out of the ground. The swallow-tail spade of the Deport gun gives good results with an axle-traversing carriage.

CHAPTER XV.

SPECIAL FORMS OF RECOIL GEAR.

Controlled Recoil.

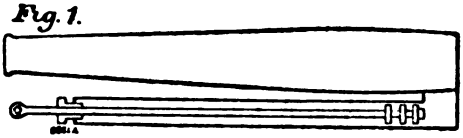
The object of controlling, as opposed to permanently regulating, the recoil, is to vary the length of recoil at different elevations. This system is principally applicable to howitzers, in which it is difficult to find room at high elevations for the normal length of recoil without the breech striking the ground.

This is effected by the use of the Vavasseur duplex valve, as modified by Messrs. Ehrhardt, Krupp, and Vickers Maxim.

We will first consider the original Vavasseur gear, which was intended to regulate, not to control, the recoil and the run-up.

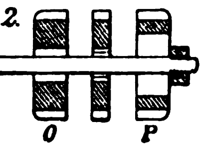
The Vavasseur valve is shewn diagrammatically in the accompanying figures.

Fig. 1.



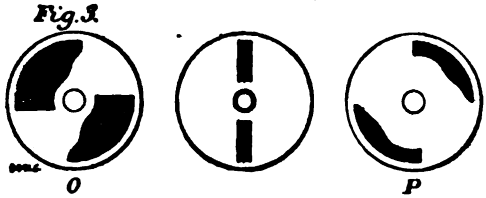
The recoil gear, Fig. 1, is of the type in which the buffer is fixed to the gun and recoils with it, while the piston-rod is attached to the cradle, and does not recoil.

Fig. 2.



The piston, Fig. 2, is divided into two parts, O and P, with a loose disc-valve between them. During recoil and during running up the glycerine in the buffer has to pass through ports in these three pieces.

Fig. 3.



The disc-valve is free to traverse from right to left, and free to revolve upon the piston-rod. The latter motion is controlled by two projections upon its circumference which fit in to rifled grooves in the buffer, causing it to turn through (say) a quarter of a circle during recoil, and to turn back again through the same angle while the gun is running up.

Now in a field gun it is desirable that the buffer resistance should diminish during recoil, as the centre of gravity of the gun and carriage shifts to the rear, and the stability diminishes. A further reduction of resistance has to be made to allow for the increased resistance of the running-up springs as they approach full compression. This graduated resistance is obtained by the shape of the ports in the piston-head P, Fig. 3.

As the gun recoils, the glycerine in the cylinder has to force its way past the piston from front to rear. The disc-valve immediately closes against the face P, so that the only passage left is the area of the curved ports in P exposed by the straight ports in the disc-valve. As the latter revolves this area first increases and finally diminishes to nothing, bringing the gun to a standstill,

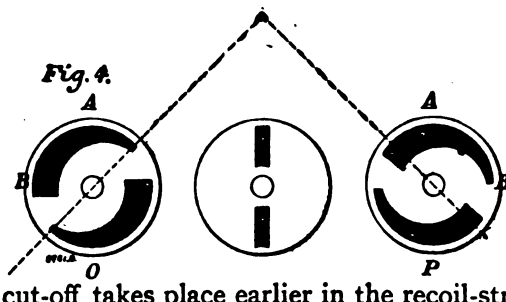
The resistance during running-up should at fist be as low as possible in order to relieve the running-up springs of all unnecessary work, and to enable them to be kept as light and slender as possible. For thick heavy springs will not stand compression beyond about 50 per cent of their length without injury. As the gun approaches its original position the resistance has to be increased to bring the gun to rest without a jerk, which would lift the spade out of the ground.

This is provided for by the ports shewn at O, Fig. 3. The disc-valve now closes tight against the face O, and the glycerine passes freely through the whole area of the ports in P, and through the whole radial width of the ports in O exposed by the straight ports in the disc-valve. As the width of the curved ports diminishes, the resistance brings the gun smoothly to rest in the firing position.

In a field howitzer the problem to be solved is somewhat different. When fired at 45 degrees of elevation the howitzer can only recoil for a limited distance without striking the ground; while if fired at a low elevation with this short recoil the wheels would lift and the carriage would be unsteady. The buffer resistance has therefore to be automatically adjusted so as to vary the recoil according to the elevation.

This is effected by Messrs. Ehrhardt's invention. The piston-rod has a bevel wheel at its forward end, gearing into a toothed segment fixed to the carriage. The effect of this is to rotate the piston-rod and piston through a portion of a circle as the howitzer is elevated.

Fig. 4.



In Fig. 4 the piston-head P has been rotated through a quarter of a circle to the left. Then during recoil the port in the disc-valve will travel from A to B, and will expose a smaller area of the curved port than if P had not been rotated. In engineering parlance, the cut-off takes place earlier in the recoil-stroke.

Howitzer running-up springs have to be powerful in order to lift the weight of the howitzer, with the recoiling parts attached to it, at an angle of 45 degrees. If the howitzer were fired at a low elevation without any resistance to running-up, the strong springs would drive the howitzer forward so violently as to upset it on to its muzzle. Therefore the buffer-resistance to running-up must be automatically increased at low elevations and reduced at high ones.

Thus, in Fig. 4, O is the forward piston-head, rotated for 45 degrees of elevation. The ports of the central valve, in running up, travel from B to A, exposing a larger area of the curved port than if the piston had not been rotated.

Further and more complex variations of resistance may be arranged for by suitably shaping the ports of the central disc-valve, or by inclining then at an angle to its diameter.

Vickers Sons and Maxim have patented a valve-gear which is very similar in principle to the above, the chief difference being that the buffer instead of the piston is automatically rotated. Messrs. Krupp, in their field guns, use the front or running-up half only of the Vavssseur gear, the recoil being regulated by varying the depth of the ports in the walls of the buffer. French makers who prefer the compressed-air gear, which gives a nearly uniform pressure in running-up, use the rear or recoil half of the Vavasseur gear for their field howitzers. Thus Messrs. Schneider, in their 1909 field howitzer (Part IV) use controlled recoil gear, which however only comes into action when the howitzer is elevated beyond 30 degrees. Messrs. Cockerill, of Seraing, prefer a channel outside the buffer, with a stop-cock which gradually closes as the howitzer is elevated.

The original Ehrhardt gear has been considerably modified since its first introduction. The piston-rod is now rotated by a cam on the carriage instead of a toothed arc. It is found more convenient to make the outer portions of the piston, O and P, traverse longitudinally instead of the central portion. The disc valves no longer fit tight against the face of the piston, but have a clearance of about $\frac{1}{100}$ of an inch, in order to allow a thin layer of liquid to remain between the rotating faces, To reduce the friction and wear which takes place in the rifled grooves of the buffer, the pitch of the rifling has been reduced, so that the valves only rotate through some 20 degrees instead of 45 degrees.

Messrs. Ehrhardt have been very successful in applying controlled recoil gear to field howitzers and to mountain guns. It has also been applied to field guns; but in these the ordinary regulating gear has now been so far perfected by Messrs. Krupp and other makers that controlled recoil gear, except as a substitute for the check-buffer, appears unnecessary.

The Rothe Recoil Gear.

A German Engineer, Herr Ròthe of Eisenach, has recently patented a new form of recoil gear for howitzers. According to him, controlled recoil gear is open to several objections. The transmission gear between elevating gear and piston is complicated and liable to damage from the enemy's fire; if placed within the cradle to protect it, this increases the size and weight of the cradle. Any play in the transmission gear seriously affects the action, since a difference in the opening of the valve of one-tenth of an inch makes a difference of several inches in the recoil. And the shortened recoil at high elevations increases the stress on the carriage, requiring increased strength and weight to withstand it.

The running-up springs have to be strong enough to lift the howitzer smartly at full elevation, hence at low elevations a considerable amount of waste spring-power has to be absorbed by the control valves, tending to run the carriage forward and to pull the spade out of the ground.

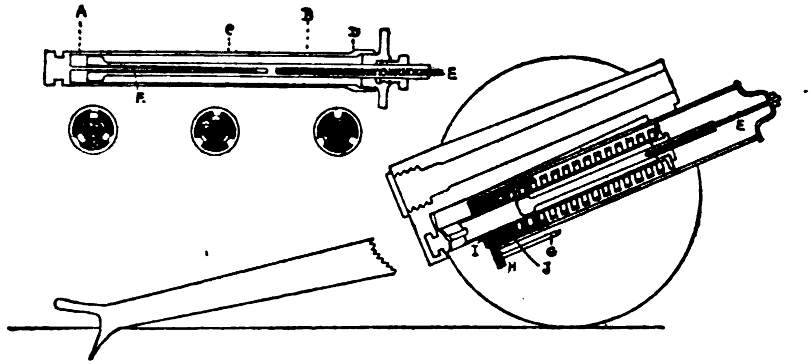


FIG. 56.

The new Rothe recoil gear is intended to overcome the above difficulties. There are no valves, but recoil is controlled by making the windage of the buffer cylinder less towards the muzzle, and shifting the piston into the narrower part of the cylinder, by shortening the piston rod, as the elevation is increased. Further, the compression of the springs is only sufficient to run up the howitzer at low elevations; as the howitzer is elevated, the spring-compression is increased by screwing up a movable diaphragm against which the springs abut.

The construction of the buffer is shown diagrammatically in Fig. 56. The buffer is longer than it would have to be if the piston were always in the same position. The solid piston is made with three notches, which are partly filled up by three tapering ribs inside the buffer cylinder. When the piston is near the muzzle end of the cylinder, the notches are nearly filled up and the resistance to recoil is considerably increased. When the howitzer is fired point-blank, the piston, before firing, is at the breech end of the cylinder, and the resistance to recoil is slight, allowing a recoil of say 40 inches. When the howitzer is fired at full elevation the piston is half way up the cylinder before firing, and the resistance is increased so as to shorten the recoil to 20 inches. In the former case the buffer cylinder, which recoils with the howitzer, moves, with regard to the fixed piston, from A to B; in the latter case from C to D.

The piston is shifted, as the howitzer is elevated, by revolving the buffer cylinder, which causes the hollow piston rod to screw itself further up the fixed screw E. An alternative method is to revolve the screw instead of the buffer.

It will be seen from the figure that at high elevations, when the piston is forward, the check-buffer F does not enter the hollow in the rear end of the piston rod to the same extent as when the piston is in the rear position; this reduces the resistance to running up at high elevations, when the springs have to lift the weight of the howitzer.

Besides this action, the effect of elevating the howitzer is to screw up the moveable diaphragm behind the springs, thus increasing their compression in proportion to the increased weight to be lifted. The inventor does not specify the exact arrangement of the gear which transmits the motion of the elevating wheel to the buffer and diaphragm; but the figure which is merely diagrammatic, will serve to explain the idea.

The spindle G is connected by bevel gearing to the trunnion-bearing, so that it revolves as the howitzer is elevated. The toothed wheel H then revolves the toothed wheel I, through the centre of which the externally-ribbed buffer slides. This revolves the buffer and piston and causes the piston rod to screw itself up the screw E.

Since the ribbed buffer passes through the centre of the diaphragm J, this also revolves with the buffer, and screws itself up the internal screw thread cut in the inner wall of the cradle, thus increasing the compression of the springs. The effort required for this is compensated by giving the howitzer a sufficient breech preponderance.

The object of Herr Rothe's invention is to increase the efficiency of the howitzer with respect to the weight to be transported. Its success depends upon the suitable and practical arrangement of the transmission gear between the elevating wheel and the working parts.

*Differential Recoil.**

This system is intended to decrease the recoil energy of a Q.F. gun or howitzer, and so enable a stable carriage to be obtained with less weight, or a gun of greater power to be fired from the same carriage without unsteadiness. Before firing the gun for the first time, it is hauled back by a winch against the springs to the extreme recoil position, loaded, layed, and released. The gun then flies forward under the action of the springs, and is fired by a tripper as it reaches the forward position. The resultant recoil velocity is then equal to the difference between the normal recoil velocity and the forward velocity imparted by the springs. On recoil the gun is held in the rear position by a catch, and is ready to fire again. If the whole of the recoil be taken on the springs, eliminating the hydraulic buffer altogether, the recoil energy—neglecting loss of efficiency from friction—is reduced to one-quarter of the normal amount. The explanation of this is as follows:—In a field gun of ordinary Q.F.

*Reprinted by permission from "The Engineer," of 25.6.09.

Page 133.—The Rothe recoil gear has since been improved. It has now a fixed buffer, and the screw E is made to revolve. The piston rod carries a crosshead connected by two rods to a diaphragm behind the springs, so that drawing the piston rod to the front increases the compression of the springs. See British patent 24826/09.

construction the powder pressure acts on the gun, driving it backwards, until the pressure is relieved by the shell leaving the muzzle, which takes place after about .008 of a second. The acceleration due to the powder-pressure produces a recoil velocity of, say, 30 foot-seconds during this period, or 15 foot-seconds in half the period, namely, .004 second. Now, let the gun, before firing, be drawn back against the springs, so that the spring pressure is sufficient to impart a forward velocity of 15 foot-seconds to it, and let it then be released and allowed to fire. Then for the last .004 second of run-up the the powder-pressure will be overcoming the forward velocity of 15 foot-seconds, and for the first .004 second of recoil it will be imparting a rearward velocity of 15 foot-seconds to the gun, so that the gun will recoil to the point from which it started. If the weight of the gun be 10 cwt., then the normal recoil energy will be $\frac{30^2}{2g \times 2}$, or 7 foot-tons, and the recoil energy with differential gear will be $\frac{15^2}{2g \times 2}$ or 1.75 foot-tons.

Following the rule that one pound of spring is capable of absorbing and giving out 40 foot-pounds of energy, to take the whole of this recoil on the springs we shall require a spring-column weighing $1.75 \times 2240 \div 40 = 98$ pounds, which is a moderate amount.

The objections to the differential gear are, first, that if the gun misses fire it will overturn on to its muzzle; secondly, that the vibration due to the action of the springs during the run-up affects the accuracy of the shooting. The first may be got over by keeping the gun low down on the axletree, or using a cranked axletree, and providing a forward buffer to stop the gun; the second objection appears insuperable so long as springs are used, and practically limits the system to compressed air equipments. A further practical objection is that when the gun is in the rear position the weight upon the point of the trail and upon the elevating gear is so great as to render the gun unhandy, and difficult to elevate and traverse.

Most of the foreign makers have constructed experimental guns on this system, in which more or less successful attempts have been made to overcome the above objections. Thus Messrs. Schneider claim that their gun, with compressed air running-up gear, can be fired from the forward position at the first round without danger and without serious unsteadiness; and that in case of a misfire the gun only runs forward, without lifting the trail. But the only differential recoil guns which have actually appeared are the Deeport mountain gun illustrated in Part IV; the French Ducrest mountain gun, successfully tried in 1907; a Krupp mountain gun, and the Krupp balloon gun described in Chapter XXI.

The differential recoil system is known by several different names. In England it is styled the *dynamic cradle;* in France, the *canon lancé;* and in Germany, the *Vorlaufgeschuetz.*

The Deport Pneumatic Recoil Gear.†

Colonel Deport, the inventor of the differential recoil gear, has lately produced a gun in which the hydraulic buffer is replaced by a compressed air buffer, which also serves to run the gun up. Provided that the orifices through which the air has to flow during the recoil stroke are suitably narrowed, there is no reason why compressed air should not be employed instead of oil or glycerine.

The action of the Deport buffer is illustrated in Fig. 57. It consists of a cylinder A, containing air at 35 atmospheres, into which the piston B is forced on recoil. The and piston is a sliding fit in the cylinder, on recoil the air has to pass from one side of the piston to the other through the hole L in the plunger F, thence through the hollow of the plunger to the interior of the hollow piston-rod C, thence down the outside of the plunger by the groove F—Fig. 58—and so through the channel H to the other side of the piston.

When the recoil is completed, the pressure of the air on either side of the piston will be equal, and the force tending to drive the piston out, and so return the gun to the firing position, will be that due to the unbalanced area of the piston rod.

During the run-up the air has to return to the other side of the piston. Since, however, the run-up must be kept comparatively slow in order not to displace the carriage by the gun running up too violently, a separate channel I—Fig. 58—and groove G are provided for the return of the air. The channel H is closed during the run-up by the valve J, which is pressed against the mouth of the channel partly by the air pressure and partly by its own inertia.

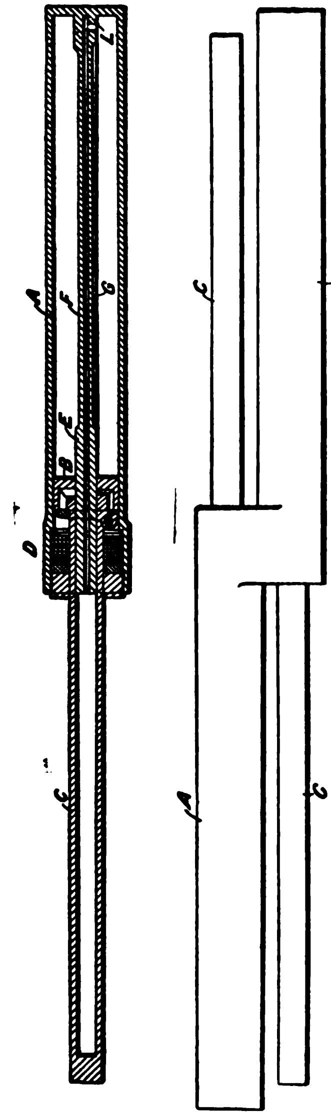


Fig. 57.

An inherent defect of compressed air recoil gear—not running-up gear—lies in the variable resistance. For the air in the cylinder, unlike the oil or glycerine in a hydraulic buffer, yields at first by elastic compression, and the piston has to travel a certain distance before the opposing air pressure balances the thrust due to the recoiling gun, and has to be relieved by the air escaping through the air channels in

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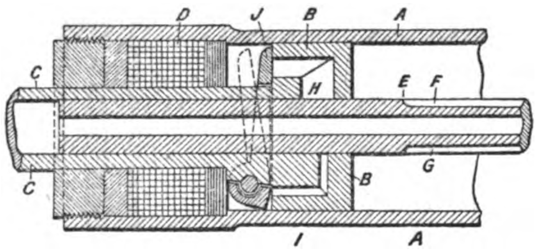


Fig. 58.

the piston. Hence a buffer on this system has to be from 6in. to 12in. longer than a hydraulic buffer, according to its sectional area, and to the initial compression of the air. On the other hand, the preliminary period of slight resistance makes the action of the gear smooth and easy, and allows the shell to escape from the muzzle before the vibration of the carriage, under the thrust of the buffer piston, begins to make itself felt.

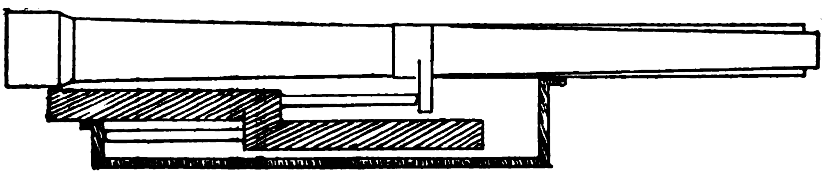


FIG. 59.

In the Deport gun it was found necessary, for the above reason, to provide for a recoil of 5 feet. A piston-rod, in compression, of this length would, however, be liable to bend unless made unduly massive, and the buffer has accordingly been made double-ended, as in Fig. 59, the stroke of each piston being 2½ft. The right-hand end of one piston is attached to the gun under the muzzle, and the left-hand end of the other piston to the rear of the cradle. The body of the buffer recoils on guides within the cradle to a distance equal to half the recoil of the gun.

Page 136.—The latest pattern of Deport gun has a compound hydraulic buffer. The gun recoils 14 ins. on the upper cradle, which is pivoted on a sleigh recoiling 40 ins. on the lower cradle. The carriage has a "scissors" trail, the two halves being opened at an angle of 60° when the gun is in action, and the points nailed to the ground *(see above.)* The gun has the semi-automatic breech action, and is capable of 50° of elevation and 25° traverse each way. It is a 14.3 pr. and weighs 20.4 cwt. in action. This gun was tried in England in 1911 and did well; it has since been adopted in Italy.

The principle advantage of the Deport gear is the lightness of the carriage. Thus the Deport gun exhibited by the Forges de Châtillon at the Franco-British Exhibition in 1908 weighed only 19.5 cwt. with shield, though of the same power as the 18 pr., which is 4¼ cwt. heavier.

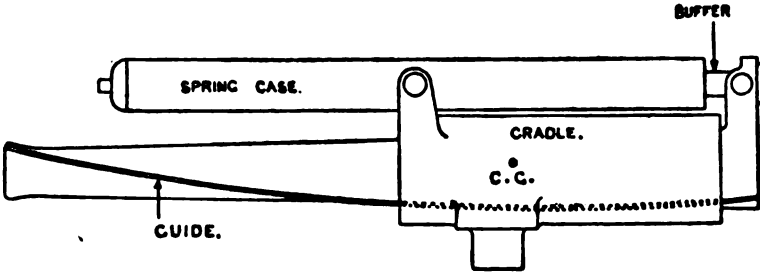


Fig. 60.

Curved Recoil.

Suppose that the cradle guides, instead of being straight, are curved so that, starting with the axis of the gun horizontal, at the end of recoil the breech of the gun will be pointing 10° upwards. This construction allows increased space for the gun to recoil at high elevations without striking the trail or the ground. And further, it assists the steadiness of the carriage at low elevations. For if the curve be struck from a point above and slightly in rear of the centre of gravity of the recoiling parts, then the first motion of the gun on recoil will be slightly downwards, and the upward velocity will subsequently be gradually communicated to the gun during recoil. That is, instead of a downward blow upon the carriage followed by a rebound, we shall have a steady downward pressure on the carriage throughout the whole length of recoil.

The calculation of the correct curve of the guides for maximum stability of the carriage under given conditions is a complex one. ... this since in practice the curve

Page 137, para. 2.—The French field gun is on rollers instead of slides, but this construction has never been repeated.

... for instance, would ... ers, which entails a construction too elaborate for field artillery.

A semi-Q.F. equipment with curved guides, on the Du Bange-Piffard system, was made for Uruguay about 1897. There was no hydraulic buffer, but recoil was checked by allowing the gun to run back up the guides. But, so far as the writer is aware, the system of recoil upon curved guides has not been applied to Q.F. guns. Apart from manufacturing difficulties, the objections to it are apparent. The buffer-cylinder and buffer-rod must have pivoted attachments; and if the sigh ts be connected to the cradle, then, unless the gun returns exactly to the same point on the curved guides after each round, errors of elevation will result. The idea is now put forward because it is becoming manifest that the power obtainable from an equipment of given weight, with straight recoil, has about reached its limit. And since the cry is still for more power and less weight, it is important to investigate any theoretical construction which promises higher efficiency.

In the Q.F. mountain howitzer especially it is exceedingly difficult to get room for a straight recoil of sufficient length to steady the carriage. It is possible that recoil upon curved guides may enable the difficulty to be overcome.

Swinging Recoil.

Messrs. Armstrong have patented a device for obtaining full recoil in howitzers at all angles of elevation. The principle is the same as that of curved guides (which may be considered to give a swinging recoil about an imaginary pivot) but the construction is different. The cradle has the ordinary straight guides, but the cradle trunnions are set high up, well above the line of motion of the C.G. of the recoiling parts, in which line the force of recoil acts. The cradle is so constructed that it is disconnected from the elevating gear after the gun has recoiled some three inches, and is then free to swing about its trunnions. The result is that at 45° elevation the gun, instead of striking the ground, swings backwards and upwards with the cradle, and comes to rest after recoil in a horizontal position, ready for reloading. When loaded, the weight of the shell depresses the breech, the cradle comes down on the elevating screw and again engages with it, and the gun is ready to fire again.

Owing to the unusually great height of the cradle trunnions, this system presumably requires a careful adjustment of balance and resistances to prevent the trail from lifting at the end of the run-up. But it gets over many of the disadvantages and complications to which other forms of howitzer recoil gear are subject, and would seem to have a future before it. So far as the writer is aware, this invention has not been carried beyond the experimental stage.

CHAPTER XVI.

ELEVATING AND TRAVERSING GEAR.

A field gun requires about 17° of elevation and 3° of depression, or a total of about 20 degrees. A howitzer requires about 45° of elevation and 3° of depression, total 48 degrees. Both gun and howitzer require a lateral traverse on the carriage of about 3 degrees each way, since the spade, when once embedded, cannot be shifted without lifting it out of the ground. In nearly all gun equipments, elevation is given by an elevating screw under the breech end of the cradle. Howitzers have usually a tooth arc attached to the cradle, gearing into a pinion on the carriage.

The Telescopic Elevating Screw.

In most carriages a plain screw long enough to give 20 degrees of elevation would project below the trail when in the travelling position, and would be liable to damage. A telescopic or Chinese screw is therefore used. This may be seen in the Plates of the various Q.F. guns. It consists of two screws, one within the other, with opposite pitches. When the outer screw is turned it rises through its nut, while at the same time it causes the inner screw to rise from within it. Thus a telescopic screw which is only one foot long when closed up is two feet long when fully extended. The outer screw is turned by a bevel wheel through which it passes, and which is capable of sliding upon it; a projection on the wheel enters a longitudinal channel in the screw, so that both turn together. The bevel wheel gears into another bevel wheel on the spindle of the elevating wheel. In some cases a second pair of bevel wheels is inserted so as to change the direction of the spindle and to bring the elevating wheel into a more convenient position.

The Krupp Super-Elevation Gear.

It has so far been assumed that the cradle guides must always be parallel to the axis of the gun. This however is not necessarily the the case. By giving the gun permanent elevation above its cradle, it is possible, at the expense of increased friction in the guides, to obtain more room for recoil at high elevations, so that the breech of the recoiling gun does not strike the trail or the ground.

In the Krupp mountain equipments the following arrangement is adopted:

The gun is not mounted directly upon the cradle, but upon an intermediate bed called a *sleigh*. This sleigh slides on top of the cradle, and is never separated from it. On coming into action, instead of connecting up the gun with the cradle and recoil gear, it is simply dropped into its place on the sleigh and secured by a keyed lug.

With this arrangement, it is a simple matter to give the gun super-elevation above the sleigh by inserting a block of suitable thickness

Page 139, first para., and page 169.—The latest field howitzers are capable of elevation up to 70°, in order to give a steep angle of descent at short ranges.

under the chase. Krupp uses a rectangular block, which can be inserted flat or on edge, giving 5 or 10 degrees of super-elevation respectively.

Effect of Super-Elevation on Steadiness.

It has been proposed (not by Messrs. Krupp) to give permanent super-elevation to field guns, in order to obtain greater steadiness. The idea is that it causes a downward pressure on the carriage which assists to keep the wheels on the ground.

We will briefly investigate the truth of this assertion.

Take the case of a gun fitted with super-elevation gear so that the axis of the gun makes an angle of 10° with the cradle guides, and suppose the gun fired with the axis horizontal. Then the gun will recoil up the guides. Let the actual recoil-velocity be 30fs.; then the gun will acquire a vertical velocity of 30 sin 10° fs. or 5fs., and a horizontal velocity of 30 cos 10°fs. This upward velocity of 5fs. is balanced by a corresponding downward stress on the carriage, tending to keep the wheels on the ground.

Now the gun attains its full recoil-velocity after about 1¼ inches of recoil, or 1/240 second; therefore the 5fs. of upward velocity is imparted to it in 1/240 second and the downward stress upon the carriage lasts only for the same time. This practically amounts to a downward blow upon the carriage, followed by a rebound from the earth. Suppose the weight of recoiling parts 10 cwt., and weight on wheels 20 cwt., then if the ground be supposed hard and the axletree perfectly elastic, the downward stress upon the carriage will be converted on rebound into an upward velocity of $5\sqrt{2}$ or 3.5 fs. imparted to the gun and carriage.

That is, under the above conditions super-elevation will be prejudicial to steadiness.

For this reason, in the Krupp equipments, we find that the super-elevation gear is not fixed, but is so arranged that it can be applied only when required. It is intended to be used only at high elevations, when the line of recoil falls within the base formed by the spade and wheels, and the question of steadiness does not arise.

The Schneider cranked axletree.

The cranked axletree has already been referred to as a means of keeping the gun down, and obtaining increased steadiness. But Messrs. Schneider use it in combination with the elevating gear in howitzers and mountain guns. Suppose the axletree normally cranked down 5 inches; then if it be rotated so that the crank is upwards this will raise the breast of the carriage 10 inches above its former position, thus giving increased elevation. Besides reducing the length of the elevating screw or arc, this gives additional space under the carriage, and affords room for the howitzer to recoil at high elevations without striking the ground. This gear is rather too heavy for a field howitzer, but finds a useful application in mountain gun and howitzer equipments.

TRAVERSING GEAR.

The Upper Carriage.

In some guns, such as the 18 pr., the cradle and elevating gear are mounted on an upper carriage, pivoted vertically to the axletree or trail, so that the cradle and elevating screw are traversed together. The cradle is then pivoted on horizontal trunnions in the sides of the upper carriage.

The Krupp Saddle.

In all German guns the cradle is provided with a single vertical trunnion upon which it traverses. In the Krupp equipments this trunnion enters a socket in a transverse saddle, which is pivoted on horizontal trunnions in the trail brackets. The saddle is extended to the rear to form the traversing bed. This is supported by the head of the elevating screw, while the cradle, on its vertical pivot, traverses on the upper surface of the bed.

In the German service gun the arrangement is similar in principle, but the traversing bed, instead of having cross trunnions, has a collar which encircles the central portion of the axletree, and turns about it.

The Axletree Pivot.

In the original Ehrhardt guns the vertical trunnion on the cradle was set directly in a socket in the axletree, so that when the gun was elevated the axletree itself revolved. It is difficult to get a good balance of the carriage with this gear. To obtain the breech preponderance necessary to eliminate play in the elevating gear, the centre of gravity of the gun and cradle must be behind the horizontal pivot, that is, the axletree. With the Krupp saddle, the horizontal trunnions can be set forward of the axletree, so that the weight of the gun partly balances that of the trail. Carriages on the axletree pivot system are no longer made.

The Swinging Pivot.

The single vertical trunnion on the cradle is known as the *swinging pivot*. It is open to the objection that when the gun is elevated the pivot is no longer vertical, so that traversing the gun alters the elevation. Moreover when the gun is traversed about the inclined pivot the sights are tilted over to one side, causing errors in direction. It will be seen that this does not apply to our 18 pr. equipment, in which the pivot of the upper carriage is vertical (or nearly so) at all angles of elevation, provided that the gun is on level ground.

The Traversing Screw.

The actual means of traversing is usually very simple. In our own equipment it consists of an endless screw gearing into a toothed arc at the rear of the upper carriage. In the German guns a screw on the traversing bed engages with a nut at the rear end of the cradle.

The French Axle-Traversing Gear.

All French guns are traversed on the axletree. The spade, which is narrow and pointed, prevents the point of the trail from moving

laterally, while the front end of the trail, with the gun, cradle, shield, and all attached gear, is shifted along the axletree so that it moves about the point of the trail as a pivot. This arrangement enables the carriage to be considerably simplified. It has also the advantage that the vertical plane of recoil always passes through the centre of the spade, whereas in cradle-traversing equipments it falls near the edge of the spade when the gun is at extreme traverse. The result is that the French type of carriage does not tend to shift sideways is firing.

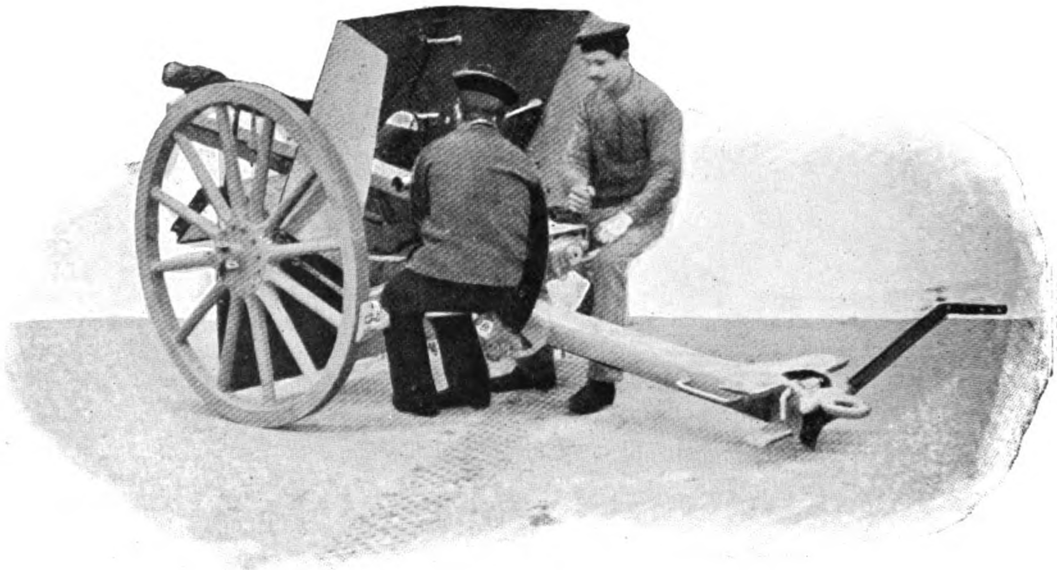
On the other hand, the axle-traversing system has several disadvantages. In order to act as a pivot, the spade must be narrow; therefore in order to obtain sufficient area to hold the gun, it must be deep. This means difficulty in getting sufficient elevation at the first round, and also in getting sufficient clearance under the spade when travelling. Until the spade is embedded, the traversing gear cannot be used. The whole weight of the gun, cradle, and shield has to be shifted along the axletree when traversing, causing considerable friction and possible jams. If the traverse be 5 inches each way, then 5 inches has to be cut off each side of the shield to keep it clear of the wheels.

It is not easy to fix the shield to the axletree, as there is then no support for the stays; but it has been proposed to fix small wing shields to the axletree, overlapping the sides of the main shield fixed to the trail. (See Chapter XVII.)

A further difficulty is that since the carriage is traversed about a fixed pivot along a straight axletree, one wheel has to move forward and the other back, creating additional resistance to traversing.

The necessity for using wide brake blocks, if the brake arms are attached to the trail, has already been referred to.

In spite of the above objections, there is no doubt that the axle-traversing system gives a stronger, lighter and more simple carriage than the cradle-traversing system. There are fewer joints, and less play and vibration. And if the difficulty about the shield can be overcome by a suitable design of divided and overlapping shield, its advantages appear to the present writer to outweigh its defects.



EHRHARDT GUN WITH SIDE SHIELDS.

1904.

CHAPTER XVII.

THE SHIELD.

The introduction of the Q.F. gun and of the long range magazine rifle have so increased the volume of fire to which a field gun is exposed in action as to render it imperative to provide cover for the detachment. This requirement has been met by the gun shield.

Prior to the introduction of guns recoiling on the carriage, several attempts were made to provide shields for the detachments. It was however found that the shield was of little use for protection, since the gunners had to step clear of it on firing. With the introduction of the Q.F. equipment this difficulty disappeared, and the size and thickness of the shield aie limited only by its weight. Every ounce of weight in a well-designed equipment has to serve a useful purpose, and it is the business of the designer to distribute the weight to the best advantage between defensive armour and offensive power.

The best distribution of weight is not easy to arrive at. It is possible to equip a gun with a shield which will keep out both infantry and shrapnel bullets at the shortest ranges. Such a shield with its attachments, 56″ high and 5′ wide, weighs about 2 cwt. Its thickness would be about 6 mm., or nearly ¼″.

The Swiss have adopted a shield 4¼ mm. or 0.167″ thick; the German shield is said to be 4 mm. or 0.1575″ thick; while the American shield is 5 mm. or 0.2″ thick. The latest equipments have shields of from 3½ to 4 millimetres. The thicknesses adopted by the different armies are given in the Table of Field Guns, Part IV.

The resisting power of shields, against the German S bullet, is about as follows:

Thickness mm.	Weight lbs. per sq. foot.	Greatest range at which bullet will penetrate. yards.
6	9.85	5
5	8.2	80
4½	7.36	140
4¼	6.96	180
4	6.56	230
3½	5.72	350
3	4.92	600

This assumes that the bullet strikes at right angles to the surface of the shield. The penetration of the French D bullet is somewhat greater than the above.

The 3 mm. thickness (approximately one-eighth of an inch) is the least that can be relied upon to keep out shrapnel bullets (41 to the pound) at short ranges, when the shell is burst close up.

Page 143. At the Chilian experiments in 1910, it was found that the Krupp 4-millimetre shield was proof against the German S bullet at 250 metres, and the Ehrhardt 5.2-millimetre shield was proof at 100 metres.

With a 4′ 8″ wheel, a shield coming up to the level of the top of the wheels and hanging within 4 inches of the ground is 20 square feet in area, so that if made 3 millimetres thick it would weigh 98.5 lbs., besides about 20 lbs. for stays and attachments.

The height of the shield depends in some measure on the method of ammunition supply. If the wagon is to be behind the gun, the shield should be 6′ high, to give cover to men bringing up ammunition from the rear; if the wagon is to be close alongside the gun, the shield need not be more than 4′ 6″ high, which is sufficient to protect men kneeling immediately behind it.

The shield is set as far back as possible, and the upper portion is sloped back to give additional protection. Our own shield is in two portions, the lower portion folding up for travelling. The German shield has in addition a top flap, which is kept down (for the sake of invisibility) till the gun is actually under fire, and is then raised, giving a total height of 5½ feet. The top flap of the Austrian shield can be folded back horizontally, giving a certain amount of overhead cover.

Shields for axle-traversing equipmeuts.

With a gun which traverses on the axletree for 5 inches either way, the edge of the shield must be 6 inches clear of the wheel, leaving an unprotected space on either side. For the shield must be fixed to the trail, since there is no means of attaching shield-stays to the axletree. This difficulty may be got over by fixing small wing-shields to the axletree, overlapping the main shield and supported by it. The proposed arrangement is shown in the above figure. The overlap increases the area of the shield by about 2 feet.

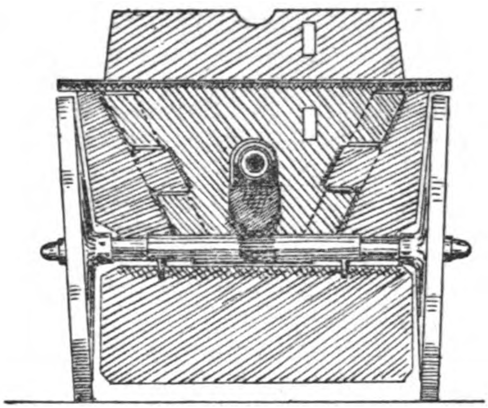


FIG. 61.

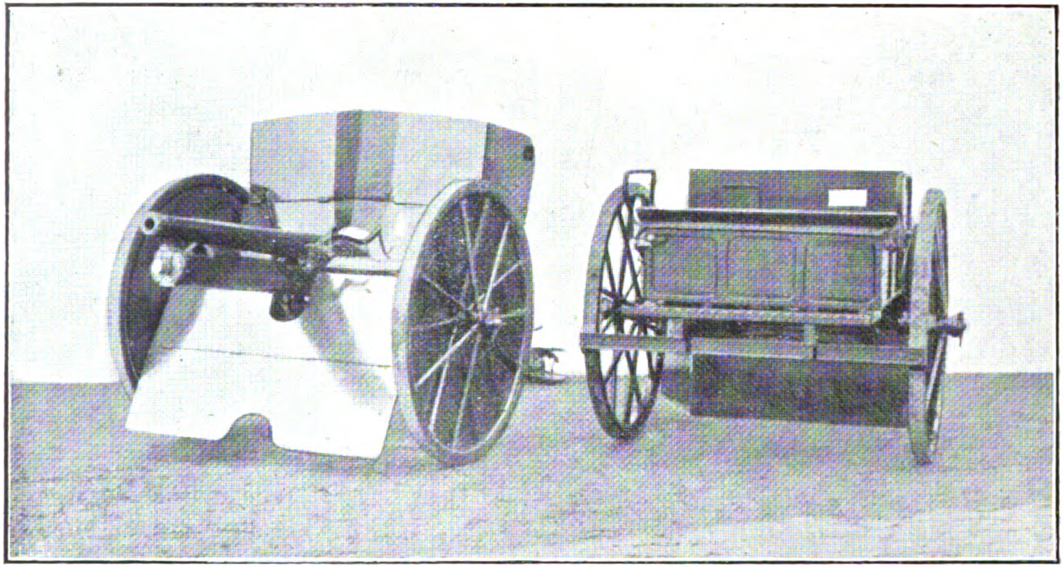
Visibility.

A flat square gun shield makes a conspicuous target and must be painted a dull colour and mottled or clouded to reduce its visibility. Even so it is apt to show up when it catches the light. It will probably be found necessary to break the flat surface of the front of the shield by carrying small stores on it.

Covering the front of the shield with sheepskin with the wool on makes it less conspicuous. At Spion Kop the Boers covered the shields of their poms-poms with sacks to prevent us from locating them.

Shields are usually made of hard nickel or nickel-tungsten steel. Messrs. Ehrhardt use steel with a tensile strength of 105 tons per square inch.

Page 144.—The latest axle-traversing equipments have hinged flaps to the shield to close the gaps between shield and wheels.



EHRHARDT FULLY-SHIELDED GUN.
1903.

THE WAGON SHIELD.

Since the normal method of coming into action is "wagon supply," with the wagon and limber, or wagon body, close beside the gun, the wagon shield is no less important than the gun shield; for in a Q.F. equipment three men are employed in preparing and supplying ammunition, while only the same number, including the No. 1, are employed in the service of the gun.

In the French equipment, in which the wagon body is up-ended alongside the gun, the bottom of the wagon body is armoured and the bullet-proof doors open outwards, giving a wide protected area. In equipments in which the wagon and limber are placed alongside the gun, the wagon body opens to the rear and the door hangs down to the ground, so that men kneeling behind the wagon are completely protected.

Shell versus Shield.

A high-explosive shell which strikes a gun-shield explodes in the act of passing through, tearing a large hole in the shield and damaging the vulnerable parts of the gun and carriage. The effect of the splinters is not only to kill every man at the gun but also the men at the wagon alongside. As against the H.E. shell, then, the shield does not contribute to the safety of the detachment but decidedly the reverse. It has therefore been proposed to make the shield hinged so that it can be folded up when desired. An example of this construction is shown in the annexed Plate, which represents one of Messrs. Ehrhardt's designs. Side shields, as in the Plate, have been proposed, both to protect the detachment from diagonal fire and to limit the effects of the burst of a shell. Both hinged shields and side shields have many advantages, the principal objection being the increase of weight.

When attacked by percussion shrapnel the disadvantages of the shield are less marked. All attempts to make a shrapnel burst in the act of passing through a shield have so far proved failures, except when dangerously-sensitive fuzes were used. It is found in practice that the shrapnel punches a clean hole in the shield, and bursts from one to two yards behind it.

Usually the man at the handspike is killed by the bullets, but none of the numbers are struck unless they are in the path of the shell.

Against percussion shell of both kinds, therefore, the protection afforded by the shield may be considered to be a negative quantity; but this disadvantage is far outweighed by the practically complete protection of the detachment against rifle bullets down to short ranges, and against time shrapnel at all ranges and distances of burst.

Armour-piercing bullets.

The figures so far given regarding penetration apply to pointed rifle bullets, either of lead cased in nickel, like the German S bullet, or of solid bronze like the French D bullet. But when these bullets are made of steel, or even with steel cores or tips, their penetration is considerably greater.

A pointed steel Mannlicher bullet will penetrate a 5 mm. shield at about 400 yards, and a steel shrapnel bullet, if the shell be burst close up, will penetrate a 3 mm. (0.118″) shield at medium ranges.

Thus Messrs. Krupp in 1902 succeeded in getting 10-gramme steel bullets (45 to the pound) through a 3 mm. shield at 3500 metres. Only a small proportion of bullets penetrated, and these were probably from shell burst close up to the shield. On the other hand Messrs. Ehrhardt found that a 4 mm. shield (0.157″) kept out the steel bullets even at short ranges.

This being so, there would appear to be no object in adopting steel shrapnel bullets unless one's opponent were known to be equipped with gun shields of less than this thickness; and even then the use of steel bullets would entail a loss of efficiency against infantry, for the steel bullets, being less dense than the ordinary mixed metal bullets in the proportion of 8 to 9, do not carry so far and are less effective against troops in the open; and, to add to these disadvantages, the larger size of the steel bullets sensibly reduces the number that can be packed in a shell.

Thus Messrs. Krupp found that their field shrapnel which normally held 300 mixed metal bullets of 11 grammes (41 to the pound) would only hold 265 steel bullets of 10 grammes (45 to the pound).

The Austrians are experimenting with a steel rifle bullet weighted with a lead mantle which extends over the base and body of the bullet as far as the shoulder. This again is covered with a nickel-silver envelope extending from the point to the base of the bullet. The idea is that on impact upon a shield the steel core will pass through it, leaving the lead mantle behind.

CHAPTER XVIII.

PRINCIPLES OF CONSTRUCTION OF AMMUNITION.

We cannot here afford space to go into the details of ammunition manufacture. But the design of ammunition is at least as important as the design of the gun or carriage, and requires careful study.*

Fixed Ammunition.

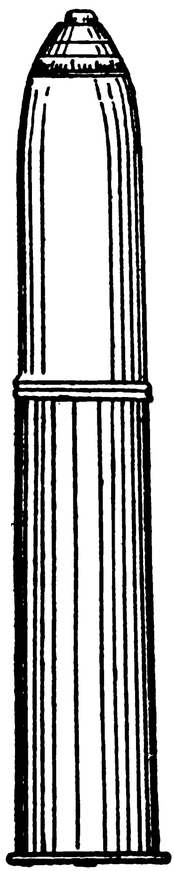


FIG. 62.

All modern field guns now use fixed ammunition, the powder being contained in a brass or bronze cartridge case similar to that of a rifle-cartridge. The shell, which is always carried fuzed, fits tightly into the front of this case.

The principle advantages of fixed ammunition are rapidity of handling, and the abolition of a separate friction tube and lanyard. Another important advantage is that no asbestos pad or obturator is required on the breech-screw, since the metallic cartridge expands on discharge so as to prevent any escape of gas to the rear. Difficulties of packing have been overcome by the introduction of honeycomb ammunition boxes, opening to the rear, in which each round of ammunition fits into a separate tube. A removable clip on the base of the cartridge facilitates its withdrawal from the tube, and at the same time protects the cap from accidental blows.

The Powder.

Smokeless powder is of two principal types, called gun-cotton powder or nitro-glycerine powder, according as one or other of these ingredients predominates in its composition.

Generally speaking, nitro-glycerine powder is both more powerful and more uniform in action than gun-cotton powder. The principal objection to it is the very high temperature developed on explosion, which, when large charges are employed, is above the melting point of steel. For this reason its use materially shortens the life of heavy guns.

Gun-cotton powder is free from this disadvantage, but requires to be used in larger quantities, necessitating a large powder chamber and corresponding increase of weight in gun.

*NOTE. The design of ammunition with reference to the firing stresses to which it is subjected has been ably dealt with by Captain Freeth, R.G.A., in the R.A. Journal, 9. XXXII and 1. XXXIII.

Cordite.

For the purposes of the English Army, which has to fight under extreme conditions of heat, cold, dryness, and moisture, the best powder is found to be a mixture of nitro-glycerine and gun-cotton. The composition of cordite is given in the Treatise on Ammunition as:

58 parts nitro-glycerine.
37 „ gun-cotton.
5 „ vaseline.

the last-named ingredient serving to render it waterproof and to increase its keeping qualities.

A new powder called "Cordite M.D." has lately been introduced both for field and heavy guns; this contains a larger proportion of gun-cotton, namely, 30 parts nitro-glycerine, 65 gun-cotton, and 5 vaseline, and gives lower temperatures in the bore.

Ballistite.

This powder consist of equal parts of nitro-glycerine and gun-cotton, with some camphor added. It is more powerful than cordite, giving about 10 per cent. higher velocities. Its keeping qualities are however inferior to those of cordite, and it is not used in the English Army.

Tubular Powder.

Both cordite and ballistite are now frequently made in the form of tubes instead of cords. The internal diameter of a tube is more constant than the area of the interstices between the cords, so that the tubular form affords more regular ignition and more complete combustion of the powder.

Tape or Strip Powder.

As a substitute for tubular powder, tape powder, or powder consisting of strips of flat, waved, or girder section, is sometimes used.

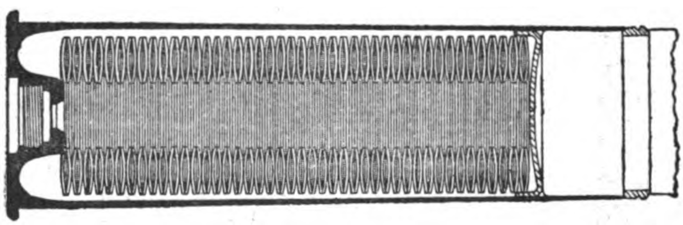


FIG. 63.

Disc Powder.

Krupp has lately introduced powder in the form of slightly cupped discs with a central hole. It is claimed that this gives remarkably regular pressures.

Tablet powder.

In Austria, gun-cotton powder is made in tablets or lozenges pressed hard. The idea is that soft powder like tubular cordite is crushed together by the pressure developed by the part of the charge first ignited, whereas with tablet powder the interstices remain open. German N.G. powder is made in cubes of 1 cm. side, partly for the above reason, partly to give slower combustion.

Ammonia Powder.

These powders are safe, powerful, and regular in action. The only objection to them is that they absorb water from the air, which necessitates their being kept in air-tight cases.

Continental Powders.

Germany, Austria and Russia use gun-cotton powder, usually in the form of leaves, for field guns. But for field howitzers it is found that nitro-glycerine powder in dice (more recently, in leaves) produces better results, giving more regular ignition with low charges. These nations therefore use two natures of powder, G.C. for field guns and N.G. for field howitzers. The French and American powders are practically pure gun-cotton, and do not keep well. The Americans now tint their powder pink with rosanilin, which fades when the powder begins to decompose, thus affording an index of its condition. The Italians use ballistite in sheets, rolled to fit into the cartridge; this is called *filite*. Other nations use French or German powders, according as their equipment is made in one or the other of those countries.

DETONATION.

Explosion may take place in two ways, by burning or by detonation. In the first case the flame from the exploding charge is quickly communicated to all the exposed surfaces of the cords or tubes of powder, and each cord burns with a rapidity proportional to its exposed surface. In the second case, when the explosive substance *detonates*, the initial force of the explosion is sufficient to break down the structure of the cords, etc., of powder so that the flame is not only communicated to the surfaces exposed but reaches every particle of the mass. This instantaneous ignition is called *detonation.*

Some substances are more easily detonated than others, the most sensitive ones being known as fulminates.

Detonating substances are useless as propellants, since the force is generated so rapidly as to expend itself on destroying substances in contact with it instead of projecting them to a distance. In the same way, it will be found difficult, for instance, to close an open door by a sudden blow. A violent kick might break a panel and yet hardly move the door, while a steady push with the finger would close it at once.

Partial Detonation.

When a high-explosive substance is ignited (not detonated) in a closed vessel, then it may happen that before the walls of the vessel give way the pressure rises high enough to break down the structure

of the still unburnt portion of the explosive, and cause it to detonate. This frequently happens with a H.E. shell with a weak detonator or weak primer.

Similarly, when large masses of gun-cotton, cordite, etc., are burnt unconfined, the temperature and pressure may rise high enough in the interior of the pile to produce partial detonation.

Action of Smokeless Powder.

All smokeless powders are of gelatinous or horny structure. The object of this is to prevent the instantaneous penetration of the burning gases to every particle of the powder, and so to allow the powder to burn steadily instead of detonating. All smokeless powders are liable to detonate if sufficient violence be used; thus, if a gun-cotton primer and detonator, as used for demolitions, were inserted into a cordite charge before firing, the effect would probably be to destroy the gun. Even a strong fulminate percussion cap is sufficient to produce partial detonation and excessive pressure in the powder chamber. When smokeless sporting powders were first introduced, owners of high-priced breech-loaders occasionally discovered this to their cost. Accordingly with smokeless cartridges a cap consisting of chlorate of potash, sulphide of antimony, and ground glass is used. With the service ammunition detonation of the charge in the bore is considered to be impossible.

Sizes of Smokeless Powder.

The more finely the powder is subdivided the more rapidly is the flash promulgated through the cartridge. Powder is accordingly made up in leaves, grains, cubes, cords, or (more recently) tubes, and the size of the cords, &c., is regulated so as to provide as far as possible for the combustion of the whole of the powder before the shell leaves the muzzle—or rather, by the time the shell has travelled two-thirds of the way up the bore—without giving rise to an unduly high pressure in the powder chamber. This description of cordite used in field guns is known as "size 5."

Primers.

Smokeless powder is difficult to ignite in a cartridge without the use of a primer to convey the flash from the cap. Formerly black powder was used for this, giving a considerable amount of smoke at the muzzle. Primers of specially manufactured smokeless powder are now used, as primers of ordinary E.C. or Schultz were found to give high and irregular pressures. Krupp uses "powder-cloth," or cloth woven from gun-cotton yarn. But a thoroughly satisfactory primer, giving perfect freedom from smoke, good and regular ignition, and of good keeping qualities, has yet to be discovered. As regards the two latter points, black powder is so far unequalled. The French use compressed black powder, moistened with soluble gun-cotton, and claim that a relatively small quantity of this gives good ignition.

It may here been noted that a good deal of the smoke which is produced on the discharge of a gun firing smokeless powder is due to the ignition of abraded particles of the copper driving band.

Effect of Temperature on Ballistics.

It has been found by experiment that in field guns each degree of temperature of the charge above or below 80° F. makes a difference of plus or minus 2.5 fs. in muzzle velocity. At practice for range and accuracy, from which range tables are compiled, the cordite cartridges are kept at a uniform temperature of 60° F. Thus, if the M.V. of a gun be given in the Range Table as 1580 fs., then with the thermometer at 75° the M.V. should be $1580 + 15 \times 2.5 = 1618$ fs. and, with the thermometer at 35°, $1580 - 25 \times 2.5 = 1517$ fs.

Therefore fuzes will tend to burn long on a hot day. This may be kept in mind by the alliterative line—

"Shorten your shrapnel fuze in sweltering summer."

Keeping Qualities of Cordite.

Cordite is found to deteriorate or partially decompose when exposed for long to temperatures above 125° F. Under very trying conditions, as on service in India, ammunition boxes should therefore be protected with blankets. The temperature in cordite magazines should not exceed 100° F. When cordite is frozen, the nitro-glycerine is apt to sweat out, and the cordite is then dangerous to handle. The nitro-glycerine will be re-absorbed when the temperature rises to 45°.

Cordite is unaffected by damp, and cartridges may be safely fired after immersion in water.

HIGH EXPLOSIVES.

Lyddite.

This is the Service burster for high-explosive shell, and is stated in the Treatise on Ammunition to consist of picric acid, melted and poured into the shell, where it solidifies. It is then a yellow mass of about the consistence of roll sulphur. Picric acid is one of the safest of known explosives, having been used in manufacture for many years before its explosive qualities were discovered. It requires a primer of dry gun-cotton or picric powder (ammonium picrate) to detonate it. ... several other countries as a ... Japanese

Pages 151, 153, 274 and 292.—The French no longer use melinite as a shell-burster. Is has been superseded by a mixture of 40% picric acid and 60% nitrated cresol, known as "cresylite No. 2", with an initial exploder of powdered picric acid, detonated by a fulminate cap.

The results obtained from our 5 howitzer, ... a lyddite shell, in S. Africa are thus described—

"Usually the effect of the burst is to produce a small crater from which the green and yellow fumes of burning lyddite arise. Frequently the shell breaks across, the front half being found in the hole; the bulk of the fragments are found lying within a radius of 20 yards."

Ammonal.

This consists of 75% ammonium nitrate, 5% carbon, and 20% metallic aluminium. Various similar compositions are used, in some of which the carbon is replaced by a hydro-carbon such as heavy oil, while others contain chlorate of potash to make the composition more

Page 151.—The Schneider fulminate fuze for H.E. shell contains 55 grains of fulminate pressed into a solid block, in which form it is claimed to be perfectly safe. A freezing mixture is used to prevent the fulminate from exploding during the pressing.

lively. The later forms of ammonal contain a portion of trinitoluol. Ammonal is not easy to detonate without fulminate, but it can be made to explode with great violence by the use of a primer of ammonia powder. The violence of the explosion is due to the very high temperature generated by the burning of the aluminium dust.

Ammonal powders.

These are intended for use as explosives, not propellants. They are all deliquescent. A few of the various compositions are:

Roth, of Felixdorf, Austria:

Nitrate of ammonia	84.5
Nitrate of potash ...	1.5
Carbon ...	8.0
Aluminium ...	5.5
Nitrate of barium ...	0.5
	100.0

Mayz, of Felixdorf, Austria:

Commercial nitrate of toluene	30
Nitrate of ammonia	47
Aluminium ...	20
Carbon ..	3
	100

The same maker:

Trinitrotoluene ...	22.2
Binitrotoluene ...	8.3
Nitrate of ammonia	46
Aluminium ...	16.8
Wood charcoal ...	4.7
Sawdust ...	2
	100.0

This powder melts at 75° C. and deflagrates at 202° C.

Schneiderite is a form of ammonal used by Schneider of Creusôt for H.E. shell bursters. It consists of 88% ammonium nitrate, 11% binitrate of napthaline, and 1% resin.

All varieties of ammonal, including Schneiderite and the new Spanish shell powder, are strongly hygroscopic, and liquefy when exposed to the air. They are useless unless kept inside a shell under a metallic seal.

Trinitrotoluol.

This substance, otherwise known as trinitrotoluene or T.N.T., is a coal-tar derivative analogous to benzene, and is represented by the formula $C_6H_2 (NO_2)_3 CH_3$. It is a yellow crystalline body of specific gravity 1.5, and melting point 82° C. It does not produce poisonous fumes, and it does not form explosive salts when in contact with metals. When ignited it burns slowly with a sooty flame. It is comparatively insensitive to blows. When detonated it explodes with about the same force as picric acid.

T.N.T. is a very safe explosive, and the only objection to it is the difficulty in getting it to detonate without a strong fulminate primer. It can however be detonated by a relatively small primer of 2 grammes (30 grains) of fulminate of mercury, by using an exploder of loose

Page 152.—Macarite is used in Belgium for filling field H.E. shell. It consists of 28 parts T.N.T. and 72 parts nitrate of lead.

T.N.T. crystals. Progressive detonation (see below) enables the fulminate primer to be still further reduced; it is stated that fulminate can be dispensed with altogether, but this is doubtful.

T.N.T. is poured into the shell melted, and allowed to solidify. By subjecting it to compressed-air pressure while cooling it can be brought up to a specific gravity of 1.65, or rather higher than lyddite.

A mixture of 95% T.N.T. and 5% napthalene is still more sluggish, and is warranted to go through an armour plate without exploding till it gets inside.

Trotyl is the German name for T.N.T.

Triplastite.

This is a gelatine of binitrotoluol and gun-cotton. It is very sluggish. Its advantage lies in its small bulk; thus 25% more T.P.T. than lyddite can be got into a shell.

Cresylite.

This is nitrated cresol; it is a safe explosive, easy to detonate, and of moderate power.

Trinitrocresol.

This is similar in its properties to picric acid, but is less sluggish.

Pertite.

This is used in Italy. It is pure picric acid.

Ecrasite. *

This has been tried in Austria for shells, and abandoned in favour of ammonal. It consists principally of picric acid.

Nitro-guanidin.

This consists of gun-cotton powder with which finely-divided carbon is mechanically incorporated. It is claimed that it gives low temperatures in the bore. It has not been tried on any extended scale.

Continental Shell Powders.

On account of the difficulty of getting lyddite to detonate in a field shell, there was a tendency, some years ago, to abandon it in favour of gun-cotton. It was found, however, that gun-cotton powder did not keep well, even in a shell. The Krupp method of progressive detonation described below has to a great extent overcome the difficulty experienced with lyddite, and all the nations which have Krupp equipments (except Switzerland) now use this explosive. The French use melinite, which is picric acid with the addition of a little mineral oil. The Germans have abandoned picric acid (C/88) in favour of C/98, which consists of specially-manufactured gun-cotton powder. It is stated that the Russians use the same. The Swiss use the same gun-cotton powder in the shell as in the charge. Austria, and the nations which have purchased Schneider equipments, use ammonal. The Italians use picric acid in their new Krupp shells. The United States have tried picric acid and various compositions with indifferent success: one of these, Dunnite, consists of picric acid, dinitrobenzol and vaseline. The Japanese, during the war, used Shimosé, which is pure picric acid, with a strong fulminate primer; the nature of their present explosive is doubtful. Krupp now supplies H.E. shell loaded either with Trotyl (T.N.T.) or picric acid.

Page 153.—Ecrasite is nitro-cresol, bearing the same relation to cresol as lyddite to phenol. It is used in Austria for howitzer shell.

THE SHELL.

Field Artillery projectiles are either shrapnel or high-explosive shell. Common shell and case-shot may now be considered as obsolete.

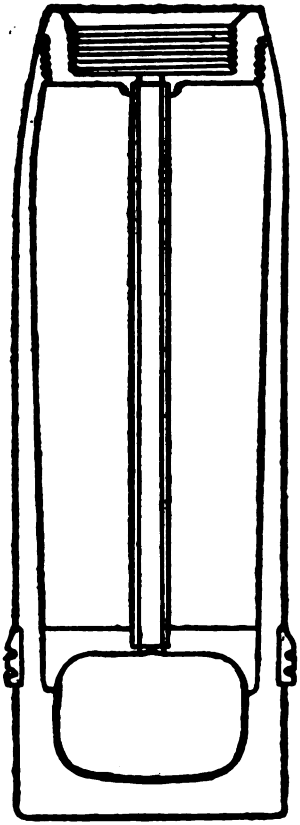


FIG. 64.
EHRHARDT 75mm. SHRAPNEL, 1904 Pattern.

This shrapnel weighs 14.3 lbs fuzed with aluminium fuze, and contains 305 mixed metal bullets of 42 to the pound, pressed in. The driving charge consists of 3 oz. of fine grain black powder, and the central tube is filled with pellets of compressed powder. A smoke producing charge of 1¾ oz. coarse black powder is poured among the bottom bullets.

Shrapnel.

The annexed figure gives a section of a modern shrapnel without the bullets. The action and general construction of a shrapnel shell being well known, it is only necessary to describe the peculiarities of this particular design which affect the shooting.

In the first place, the shrapnel body is intended not to break up on explosion, but to act as a short gun and to propel the bullets forward with the maximum attainable velocity. For this purpose the shell has a large powder chamber, intended to contain a driving charge of 3 oz. of fine-grained black powder. Messrs. Ehrhardt, the makers of this particular shell, have found by experiment that the driving-charge gives an increased velocity of 350 fs. to some at least of the bullets. But it is considered probable that the *average* extra velocity imparted to the bullets is not more than 200 fs., as most of them escape centrifugally before the full force of the charge is developed. (See Chapter on Shrapnel Fire.)

The walls of the shell are made as thin as possible, in order to get in the greatest possible weight of bullets. For this reason the shell is made of hard and tough nickel steel, pressed hot from the ingot and afterwards drawn out hot by passing through successive dies.

It will be observed that the body of the shell is contracted at the shoulder. The object of this "choke-boring" is to get a closer pattern with the bullets, the idea being that the outer ring of bullets get an inward impulse from the incurved shoulders of the shell which reduces their centrifugal velocity. The soundness of this theory has not been conclusively proved. This form of body, however, gives facilities for getting the greatest number of bullets into the shell, and the makers consider this a sufficient reason for adopting it.

The diaphragm separating the powder from the bullets is a steel drop-forging, and is flat instead of conical so as to give the minimum dispersive effect on the bullets. It is supported by a shoulder in the wall of the shell, into which it fits tightly. There is no tin cup to

contain the burster, but the powder-chamber has a smooth internal coating of lacquer.

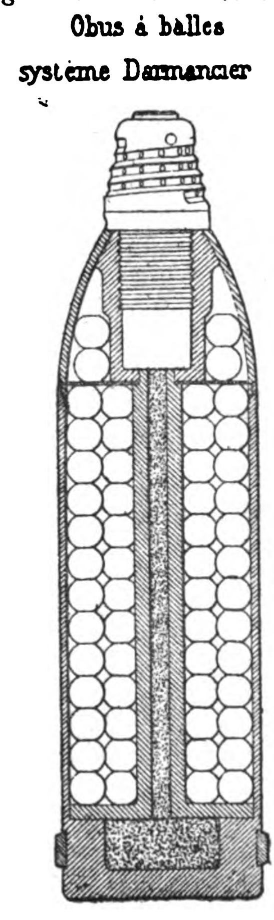
The curve of the head and shoulder of the shell is struck with a radius of 2.3 diameters, this shape of shell being found to keep up its velocity much better than one with a head of only 1½ diameters. The latest pattern of Russian shrapnel has a head struck with a radius of no less than 2.75 diameters, and the St. Chamond shell shown in the Plate have 3-diameter heads.

The principal objection to these extra long heads is the loss of bullet capacity which results from their use. It is estimated that a 15-pr. shell with 2-diameter head holds 8 more bullets (42 to the lb.) than a shell of the same total weight with head struck with 3-diameter radius.

A smoke-producing charge of 1¾ oz. of coarse black powder is poured in among the bottom bullets, and the bullets are consolidated by pressure, a dead-weight pressure of 10 tons being applied three times during the filling of the shell. The object of this is first to prevent prematures, due to the grinding of the smoke-producer between the bullets on discharge, by consolidating the bullets so that they cannot move; and in the second place, to get the maximum number of bullets into the shell.

The bullets are further secured by pouring melted resin into the interstices.

Another form of field shrapnel, specially devised to contain a large proportion of bullets and to give a regular dispersion of the bullets, is the old Darmancier shrapnel shewn in Fig. 65. It will be noted that the diaphragm and central tube are in one piece, so as to prevent the powder-gases from penetrating among the bullets and scattering them irregularly. The bullets are flattened so as to have a firm regular bearing upon each other. These shrapnel used to give very good results.



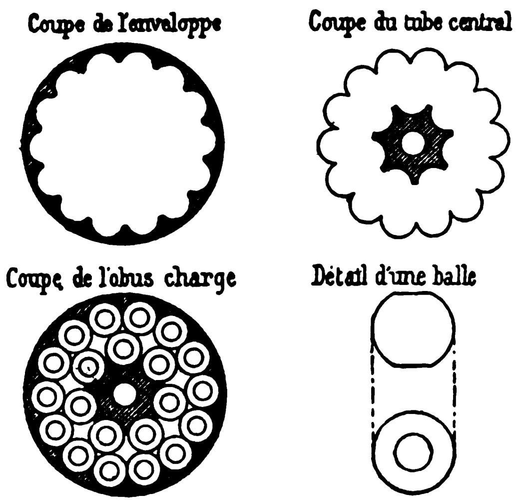


FIG. 65.

Proportion of Weight of Bullets to Weight of Shell.

In the above-mentioned Ehrhardt shrapnel, fuzed with an aluminium fuze, the weight of bullets is 51 per cent. of the weight of the shell. The Armstrong field shrapnel (1904) contains no less than 53 per cent. of bullets, but the powder chamber is smaller than in the Ehrhardt shell.

Taking the best size of bullet as 39 to the pound, this gives 300 bullets in a 14.5 lb. shell. The same shell would hold 315 bullets of 41 to the pound, or 346 of 45 to the pound.

Cordite Shrapnel.

On inspecting the illustration already given of a field shrapnel, it will be noticed that a large proportion of the available space is taken up by the driving charge of 3oz. black powder. Now since smokeless powder occupies a much smaller space than an equivalent charge of black powder, it would appear desirable to use cordite or ballistite in the powder chamber of a shrapnel shell. If the powder chamber could be cut down to half its height a considerable saving in weight would be effected, which could be utilized in providing an increased number of bullets. The smoke-producer would then occupy the interstices between the bullets, so that no space would be wasted.

Several attempts have been made to realise this ideal, but the results have not so far been encouraging. The trouble is that the smokeless powder, when closely confined in a chamber at the bottom of a shell, detonates or partly detonates instead of burning quietly. The effect is occasionally to blow off the base of the shell, but usually to break up the shell violently, scattering the bullets in all directions.

The idea is however perfectly sound in theory, and only awaits the introduction of an explosive powerful in proportion to its bulk, and warranted not to detonate, to become a practical fact.

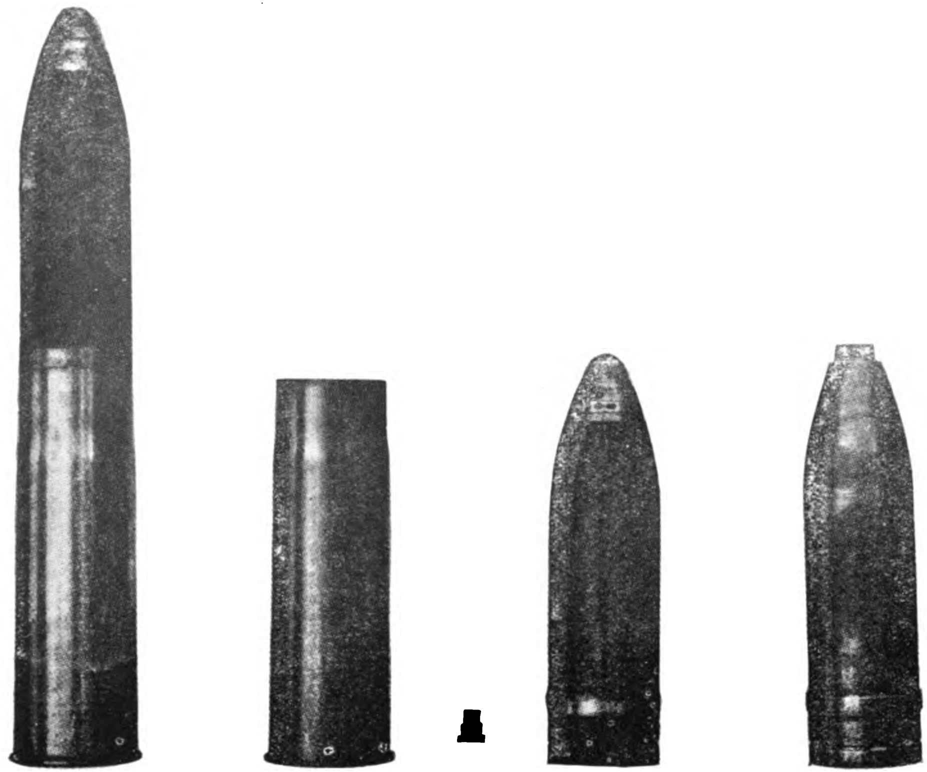
In the Krupp high-explosive shrapnel (Fig. 70) the driving charge, to save space, is in the form of a pellet of compressed black powder behind the diaphragm. But experience with compressed-powder bursters is so far unsatisfactory.

Smoke Composition.

Most modern shrapnel contain smoke composition to make the burst more visible. This is also important for another reason. The rapid fire of a Q.F. battery with smoke-producing shrapnel makes a dense cloud of smoke in front of the enemy's line, which, on a moderately still day, is sufficient to prevent him from taking effective aim.

Thus we read that at the battle of Liao-Yang, on the 30th August 1904, the Japanese artillery positions were enveloped in dense clouds of smoke, caused by the continuous explosion of the Russian shells, which prevented the Japanese gunners from taking aim.

Various smoke compositions are used, but the simplest and probably the best is coarse black powder, of which about two ounces is poured among the bottom bullets before the hot resin which fixes them is introduced. These shell at first gave rise to prematures, owing to the grinding together of the bullets on discharge. This has now been



ST. CHAMOND Q.F. AMMUNITION.

overcome by consolidating the bullets by pressure. This method has also the advantage of increasing by about 10% the number of bullets that can be packed into a shell.

Messrs. Ehrhardt have lately introduced a new form of smoke-producer. This consists of coarse-grain black powder which has been stirred up in melted resin, so that each grain is coated with resin. This is claimed to be perfectly safe from prematures.

The favourite smoke-composition on the Continent is a mixture of equal parts of black powder and red amorphous phosphorus in fine dust. Phosphorised antimony, a mixture of red phosphorus and sulphide of antimony, is also used. Yellow phosphorus gives good results but is less safe than red phosphorus. It is also objected to as liable to cause poisoned wounds should any of the composition remain adhering to a bullet. Napthaline has been tried and discarded; it is difficult to ignite.

Trinitrotoluol, melted and poured in amongst the bullets, has been successfully tried in Germany. It combines the functions of a packing for the bullets and a smoke-producer. It is quite safe against prematures, and gives a conspicuous cloud of smoke.

The Wille Shrapnel.

General Wille proposes to use elongated rifle bullets instead of spherical bullets in field shrapnel. These bullets are to be given rotation either by being strung on rifled spindles or by being enclosed in rifled barrels. In the second type the shell becomes a bundle of pistol barrels, each containing some 16 bullets, with a common driving charge behind them. General Wille expects to get over 50% of useful weight with hardened lead bullets, or nearly 60% with tungsten steel bullets. The advantages of this proposal lie in the greatly increased range of the bullets from the point of burst, and the improved penetration. Thus even the elongated lead bullets would pierce an ordinary "shrapnel-proof" gun shield at 3000 yards if burst within 100 yards, while the tungsten steel bullets would render gun-shields practically ineffective at all ranges. The objections to the proposal are, first, the expense; secondly, the difficulty of so adjusting the driving charge that it will drive out a column of 16 bullets without their setting up and jamming, and without blowing out the base of the shell. In view of the realization of General Wille's predictions in his book "The Field Gun of the Future" (1891) his present proposal should not be lightly dismissed as impracticable.

HIGH-EXPLOSIVE SHELL.

These are of two kinds, namely thick-walled man-killing shell and thin-walled "mine" or "torpedo" shell.

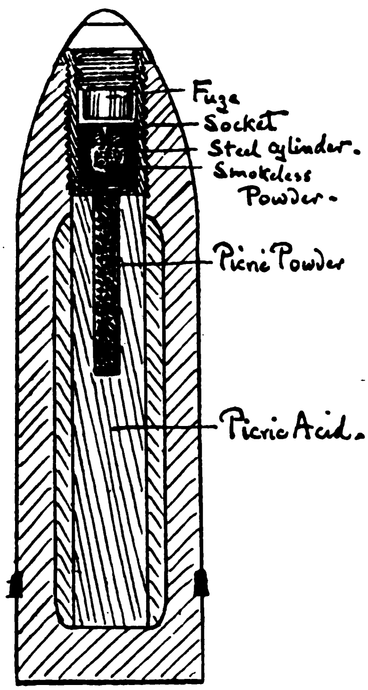
Mine shell are now rarely used in field gun equipments, since the difference of length between a shell filled with lyddite, specific gravity 1.6, and a shrapnel of the same weight, filled with bullets, is such that the two shells cannot be made to shoot alike, and a separate range-table has to be used for each shell. Mine shell are moreover dangerous, since they contain a quantity of explosive sufficient to destroy the gun if burst in the bore. They are however used in field howitzers, which require a powerful shell for attacking field entrenchments.

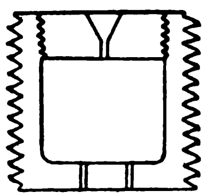
Thick-walled H.E. shell are intended for the attack of materiel and of troops behind steep cover, where they cannot be reached by shrapnel. They are of hard brittle steel, and the gun-cotton burster is only large enough to break up the shell into a sufficient number of man-killing fragments. The original German Sprenggranate was of this type, and was intended principally for use with a time fuze. The idea was that when burst in air over the crest of a parapet the splinters would strike vertically downwards, killing the men behind the parapet. But after several years of experience the Germans found that with this nature of fire the expenditure of shell required to produce a number of hits sufficient to dislodge the defenders was greater than when percussion shrapnel were used to cut down the crest of the parapet. High-explosive shell are therefore now used principally with percussion fuzes.

High-explosive shell are nearly useless against infantry in the open, as the effect is very local and the men are safe at a comparatively short distance from the point of burst.

A thin-walled "mine" shell of 2.95″ calibre contains from 12 to 14 oz. of high explosive, whereas the charge for a thick-walled shell is from 4 to 7 ounces, besides the smoke-producing charge.

A thick-walled H.E. shell does not differ very much in length from a shrapnel of the same weight, and it is possible, by modifying the shape of the heads of the two projectiles, to get them to shoot practically alike.





STEEL CYLINDER.

KRUPP H.E. SHELL.
FIG. 66.

Progressive Detonation.

Fig. 66 represents the latest design of Krupp H.E. shell. The shell is of hard steel, and is filled with picric acid or T.N.T., with a central cavity for the detonating primer (called in our service the *exploder*) consisting of ammonium picrate or T.N.T. crystals respectively. Between this and the fuze is the *detonating cylinder*. This is of hard steel, about 1 inch in diameter and $\frac{1}{8}''$ thick, and is filled with special fine-grain nitro-glycerine powder. The cylinder is closed except for a fire-hole opposite the fuze, and the small perforations at the bottom. On discharge, the flash from the fuze ignites the fine-grain powder; the cylinder bursts with great violence, and partially detonates the primer, instead of merely igniting it. The primer in turn completely detonates the bursting charge.

The bursting charge is contained in a millboard cylinder, which is inserted into the shell, the cavity around it being filled with melted pitch, or paraffin wax and resin.

Messrs. Krupp have supplied H.E. shell on this principle to Holland and other nations, and these have given very good results.

COMBINED SHRAPNEL AND HIGH EXPLOSIVE SHELL.

When the detonator of a H.E. shell fails to act with sufficient sharpness, the effect is that the picric acid or other H.E. charge does not detonate, but simply takes fire and burns. It has been proposed to take advantage of this fact to make a shell which shall be effective both as a shrapnel and as a H.E. shell.

Suppose a shrapnel shell with the bullets packed in, say, ammonal or T.N.T. (Lyddite would not do, since in contact with lead it forms picrate of lead, a sensitive and dangerous explosive.) Suppose the T. & P. fuze such as to explode the powder charge in the ordinary way when burst in air, but to detonate the high explosive among the bullets, by means of a detonating primer, when the percussion arrangement acts on impact. Then in the first case the high explosive would merely burn and act as a smoke-producer when the shell opened; in the second case the shrapnel would become an effective high-explosive shell.

The experiments with shells of this nature carried out by the French and German governments proved, at first, unsatisfactory. It was found that when the shell was burst in flight the heat produced by the burning of the high explosive (ammonal) was such as to melt the bullets, while when burst on impact the detonation reduced the bullets to powder.

But more recent experiments, in which the bullets were packed in T.N.T., gave better results, as this explosive, when burnt, produces a much lower temperature than ammonal. The best shell of this nature so far produced is the Ehrhardt shell described below. But the problem of the "universal projectile" cannot yet be said to be completely solved.

The Ehrhardt High-Explosive Shrapnel.

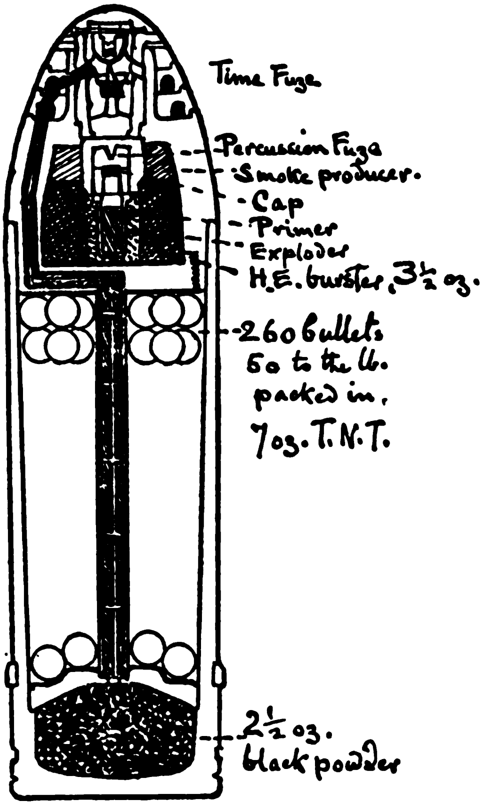


FIG. 67.

This shell has been tried on an extensive scale, and a number have been ordered by the German government.

It consists of an ordinary shrapnel body with a high-explosive head. When burst in air, the flash from the fuze passes round the high-explosive burster to the driving charge in the base. The bullets, which are packed in T.N.T., are blown out in the usual way and the head goes on and detonates on impact, affording a valuable means of observing and correcting the trajectory of the shell. When burst as a percussion shrapnel the high explosive in the head detonates and the bullets and fragments are blown out laterally. The T.N.T. among the bullets merely explodes; but if the shell strikes any solid object such as the gun itself, the detonation of the H.E. burster in the head is communicated to the T.N.T., and the shell acts as a mine shell. The head burster also serves to keep the bullets off the ground, and renders the

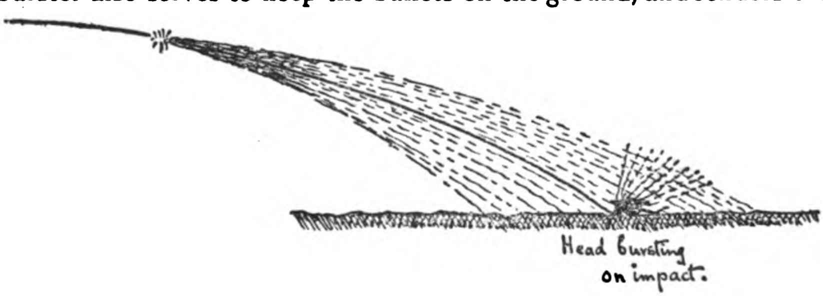


FIG. 68.

projectile more effective when burst on graze than the ordinary shrapnel.

The primâ-facie objection to this form of field H.E. shrapnel is the loss of bullet capacity; but the makers claim to get 47% of bullets into them besides the high-explosive burster, which weighs 3½ ozs., and besides 7 oz. of trinitrololuol among ~~other~~ bullets.

Pages 160—162.—High explosive shrapnel are now called "universal shell." The Ehrhardt pattern shown in Fig. 67 has been adopted for the German 4.2″ Q.F. howitzer. The latest pattern Ehrhardt 14.3 pr. universal shell contains 2.82 oz. T.N.T. in the head, 5 oz. among the bullets, and the bullets constitute 42% of the weight of the fuzed shell. The Krupp pattern shown in Fig. 70 has

been abandoned and replaced by a pattern somewhat similar to the
Ehrhardt, but with axial instead of head burster, and with the
channel connecting the fuze to the base burster set out of centre.
The front half of the axial burster flies forward with the head when
the shell is burst as a time shrapnel. The 14·3 lb. shell contains
6.85 oz. T.N.T. and 45·7% of bullets. The Schneider 14·3 pr.
universal shell is very similar to the Ehrhardt; it contains 4·7 oz.
T.N.T. in the head, 6.56 oz. among the bullets, and 43% of bullets.
Messrs. Armstrong have also a universal shell, but the details are not
published. These shells have now been adopted by the United
States and Holland for field guns, and by Germany, Austria and Italy
for field howitzers.

shield.

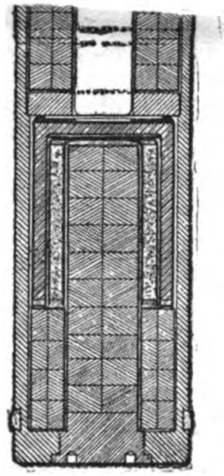


FIG. 69.

The angle of opening, as regards the segments in front of the cup, is 24° at medium ranges. This relatively small angle of opening is secured by enclosing the mass of segments in a leaden envelope which reduces the dispersion on the principle of the bullet-cage used in our 15-pr. B.L. shrapnel. The segments in rear of the burster fly out at an angle of about 120°.

This projectile cannot be expected to be effective against infantry targets. But it seems well adapted for the attack of shielded guns. For the probability of hitting a shield with a time-shell giving a 24-degree cone of segments is much greater than that of making a direct hit on it with a percussion H.E. shell.

The Krupp High-Explosive Shrapnel.

The front portion of this is an ordinary shrapnel with time and percussion fuze. The driving charge of compressed powder is seen immediately behind the diaphragm; it is said to give the bullets an additional forward velocity of 200 fs.

The rear portion is completely separated from the front portion by a partition formed in the metal of the body. It contains a charge of 1¾ oz. high explosive, inserted from the base, and a percussion fuze. The shell weighs 14.3 lbs. and contains 300 bullets of 50 to the pound, or 42 per cent. of bullets.

Pointed Shell.

All the principal military nations have introduced, or are now introducing, pointed rifle bullets, that is, bullets with only a short cylindrical portion, the remainder forming a point of some 10 calibres radius. The great improvement in flatness of trajectory and increase of remaining velocity obtained with these bullets have attracted the attention of artillerists, and the question has arisen whether anything was to be gained by making field shell of this shape. The answer has so far been in the negative. A field shrapnel is only a device for transporting a mass of bullets to within bullet range of the enemy. Any marked departure from the cylindrical shape means a considerable loss of bullet capacity. If the pointed shell were of the same weight as the ordinary shell, it would have to be considerably longer, and the walls would have to be thicker to prevent setting up. This means a reduction of useful weight. Moreover the rifling of ex-

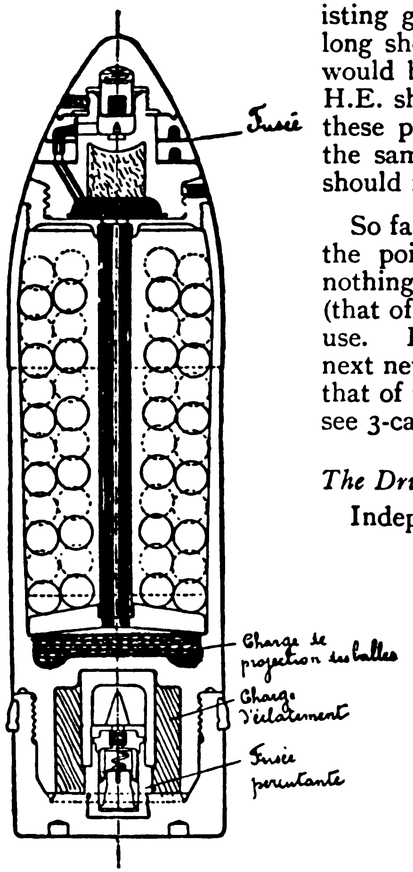


FIG. 70.

isting guns would not be suitable to the long shell, and the existing limber boxes would be too short for them. As regards H.E. shell, there is no object in making these pointed unless the shrapnel are of the same shape, since the two projectiles should range alike.

So far, therefore, no nation has adopted the pointed shell for field artillery, and nothing longer than a 2.75-calibre head (that of the Russian shell) is at present in use. But it is quite possible that in the next new field equipment (which will be that of the French field artillery) we may see 3-calibre or 4-calibre heads used.

The Driving Band.

Independently of its function in rotating the shell, the driving band serves to hold the shell from moving forward until the cartridge is fully ignited. Its thickness and hardness are found to be of considerable importance as affecting the regularity of the shooting. If too small, it allows the shell to get away too soon; if too large or too hard, it gives irregular frictional resistances towards the muzzle, where the powder-pressure is low, and so causes variations in the muzzle velocity. These, however, are matters which have to be determined by experience.

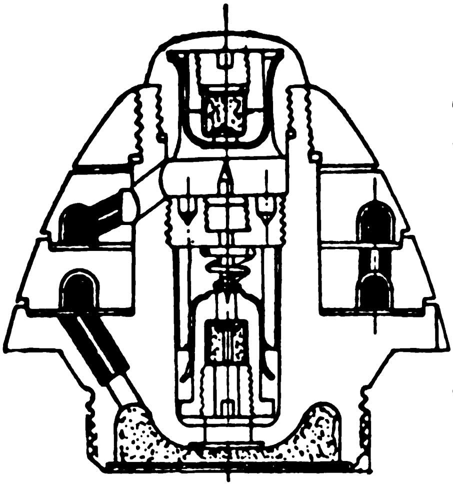
In a howitzer shell the driving band has other functions which will be referred to later.

Effect on Ammunition Boxes.

It has been found experimentally that a direct hit, either with high-explosive shell or shrapnel, on a cellular or honeycomb ammunition box does not usually explode the whole of its contents. Only the shell actually struck is exploded; the cartridges may or may not be ignited, and the effect is usually only to wreck the limber or wagon without much danger to men standing near it.

Incendiary Effect.

German experiments with H.E. shell have led to the conclusion that these are of little use for setting fire to buildings. But percussion shrapnel containing large driving charges of black powder are found to have considerable incendiary effect.



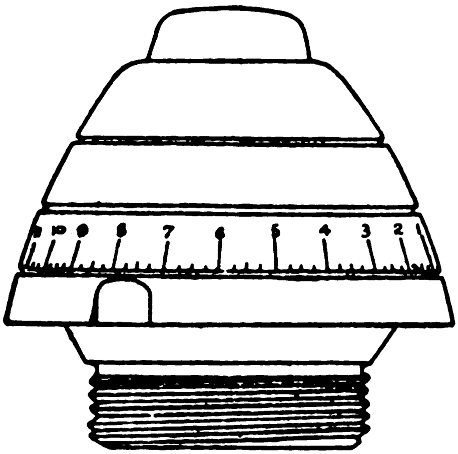


FIG 71.

FUZES.

The general action of percussion fuzes and time and percussion fuzes is well known. The type of fuze now adopted in all Q F. equipments (except the French) is the double-banked fuze shown in the next illustration.

The advantage of the double ring of composition is to give a greater length of composition, and more accurate burning. This is explained by the diagram annexed, which represents a portion of the two composition rings.

Let A be the channel conveying the igniting flash to the upper ring, B the channel from the upper to the lower ring, and C the channel leading to the powder-chamber. Then if the lower ring be shifted from zero

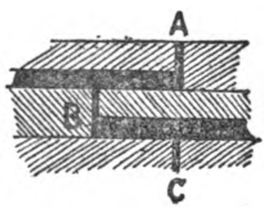


FIG. 72.

say one inch to the left, the fire has to burn round the upper ring from A to B, and then back again round the lower ring from B to C, a distance of two inches, or double the distance to which the lower ring was moved. Triple-banked and quadruple-banked fuzes on the same principle have been designed, but have not at present been introduced.

For the sake of lightness, Q.F. fuzes are made of aluminium or aluminium alloy. Since however this metal is injuriously affected by the fuze composition, the composition channels are preferably lined with brass.

The French Time Fuze.

In this fuze the composition is contained in a sealed tube of pure tin, which is wound spirally round the head of the fuze. Inside the head is the ignition arrangement. To set the fuze it is placed in the fuze-setting machine, when by forcing down a handle a piercing point

is thrust through the tube of composition into the interior space of the head, as at P. On discharge, the flash from the igniter passes through the hole and ignites the composition. The fuze is shown in Fig. 73. The head is covered by a cap with holes for the piercing

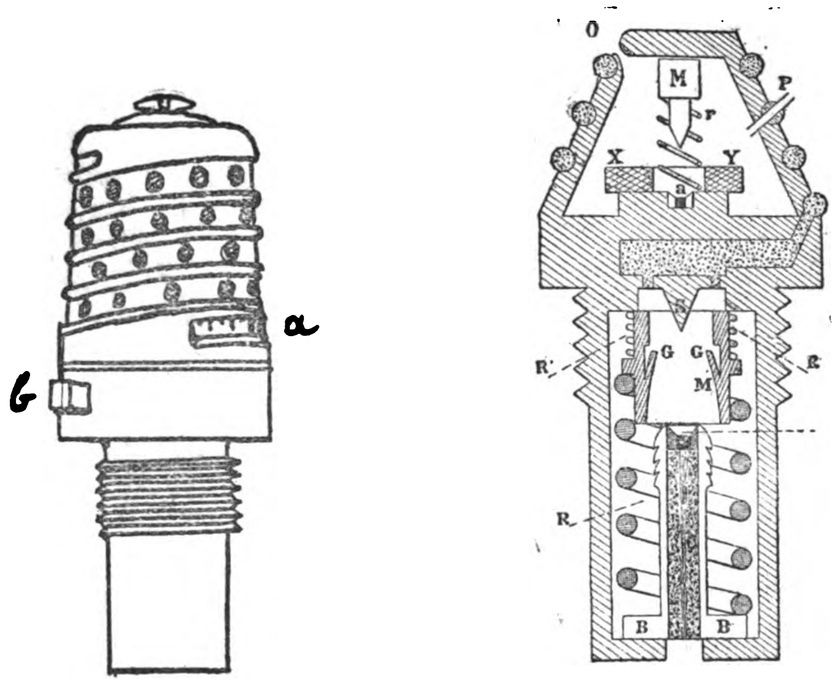


FIG. 73.

point. The whole cap can be shifted round for a short distance and set by the corrector scale at *a*. The projection at *b* is a steel stud which engages in a recess in the fuze-setting machine.

Fuzes for High Explosive Shell.

One percussion fuze which merits special description is the air-space fuze, which is intended for use with H.E. shell. The construction of this is shown diagrammatically in the annexed figure. The fuze is patented by Messrs. Ehrhardt.

(See Fig. 74.)

Let A be the fulminate of mercury detonator, B a cylindrical primer of picric acid, protected by a stout metal diaphragm on top. Until the moment of impact B is at the bottom of the fuze, leaving an air-space round the detonator, so that if the latter goes off nothing further happens—it does not even set fire to the primer, much less detonate it. On impact the primer sets forward so as to surround the detonator, and the needle carried by the primer strikes the cap C. This fires the fulminate detonator, which detonates the primer, which in turn detonates the bursting charge of the shell.

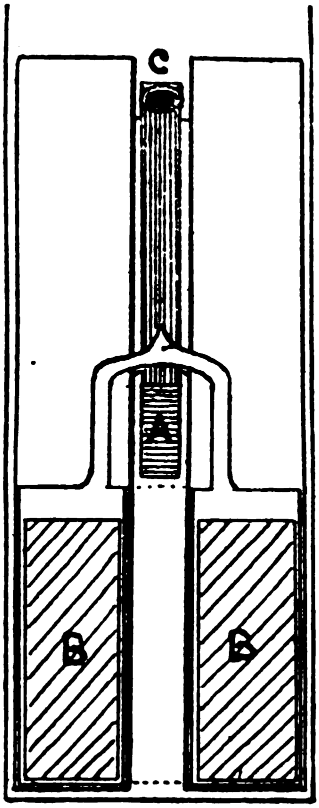


FIG. 74.

The Bofors Fuze.

The Bofors Company, Sweden, have a base fuze on a new principle. The fuze is practically a short gun inserted in the base of the shell. On impact the fuze ignites a magazine of powder: this fires a hammer with great violence against a picric powder cap, which detonates, thus securing complete detonation of the burster. This fuze is intended to give a slight delay action and is more suitable for howitzers than for field guns.

Mechanical Fuzes.

In this age of science, the measurement of time by burning fuze-composition would appear almost as antiquated as King Alfred's candle-clock. Many attempts have accordingly been made to arrive at a direct mechanical system of measurement of the *distance* from the gun at which the fuze is to act.

General Hiram Berdan, of the American Army, is the original patentee of the "distance fuze." A hanging weight suspended from a spindle pivoted in the axis of the shell was made to impart motion to worm gearing as the shell revolved about it, and, after a certain number of revolutions, to explode the shell. The distance at which this happened depended on the twist of the rifling and the velocity of the shell, and did not vary so long as the mechanism worked as intended. Many inventors have taken up this idea, and it still turns up from time to time at the War Office. But no one has yet succeeded in overcoming the tendency of the weight to take up the rotation of the shell instead of hanging straight down from its spindle.

The following are the principal types of fuze which have been tried:—

1. Fuzes in which a weight is hung from pivots in the axis of the shell while the shell rotates about it.

2. Wind-vanes fuzes, in which a vane or "flag" on the nose of the fuze is held from turning by the air-pressure, while the shell rotates.

3. Turbine fuzes, in which a turbine wheel set in the head of the shell is rotated by the air which enter the open nose of the shell.

4. Air-pressure fuzes, in which the air slowly presses in a disc in the head of the fuze.

5. Clockwork fuzes with spring or recoil escapement.

6. Brake fuzes, in which the velocity of a clockwork train is regulated by a centrifugal brake.

7. Powder-pressure fuzes, in which a train of wheels is set in motion by the pressure of the powder-gases.

8. Centrifugal water fuzes, in which the water is driven out from a central chamber, through a hole of given diameter, by the centrifugal force due to the rotation of the shell. The rate at which the water escapes is supposed to be uniform, and to afford a measure of the number of the rotations of the shell, that is, of the distance travelled. As the water escapes a spring plunger descends, and when the plunger gets to the bottom of the water-space a trigger is released and the shell exploded.

Personally I am of opinion that success is most likely to be achieved by substituting a gyroscope for the hanging weight. If a heavy fly-wheel be pivoted at right angles to the shell, hung in a frame pivoted in the axis of the shell, and if the wheel be revolved by a strong spring wound up before loading and released on discharge, then the wheel will actively—not passively, as in the case of a weight—resist any attempt to make the frame take up the rotation of the shell. If this be combined with a train of wheels arranged to release the striker after a certain number of revolutions of the shell, we shall have a theoretically perfect mechanical fuze. The practical difficulty is to make the pivots small enough to turn easily and yet strong enough to stand the shock of discharge.

Many mechanical fuzes have been invented, but so far no efficient substitute for the composition fuze has been discovered. Yet the composition fuze has many defects, and a serviceable mechanical fuze would double the efficiency of the gun. It is to be hoped, therefore, that there will arise in the Regiment some mechanical genius who will supply this long-felt want.

A good specimen of the mechanical fuze is the following:

Meig's and Gathmann's Fuze.

American Patent, 772470 of 1904. Fig. 75.

In this fuze a spindle is kept from rotating with the shell by a double flag, N, and this relative motion allows a spring to unwind. This spring turns a setting plate, which after a given portion of a revolution releases a safety bolt and allows a striker actuated by a spiral spring to fire the fuze.

Page 166.—The Krupp mechanical fuze is a clockwork fuze with an extra rapid cylinder escapement making 30 beats to the second. It is stated to be 20% more accurate than composition fuzes. It has not been generally adopted.

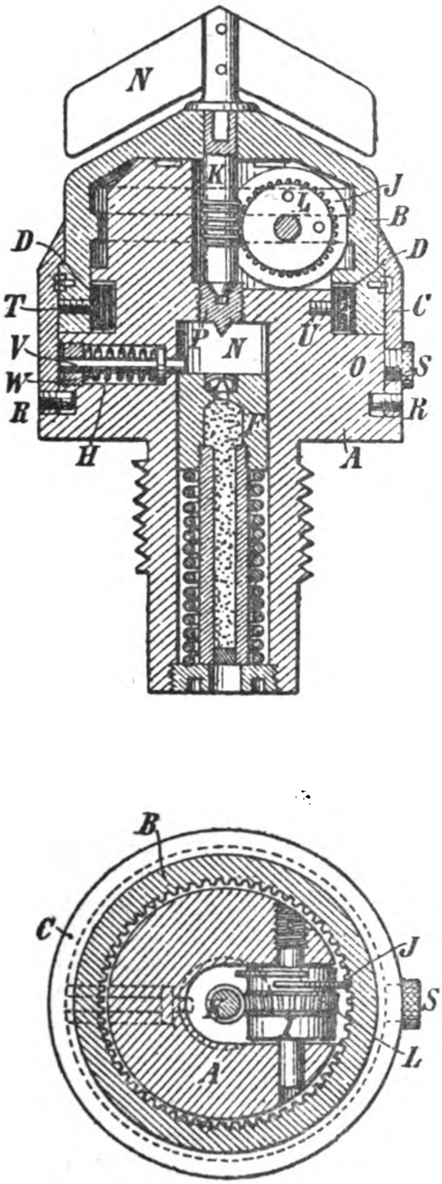


FIG. 75.

K is the spindle, stepped upon a plug P which carries the needle N. The endless screw on the spindle engages with the worm wheel L. The axle of this wheel carries the worm J carrying one turn of thread. The worm J engages with teeth inside the dome, which can be turned to set the fuze. A coiled spring D is fixed at one end to the fuze, at the other to the dome, and tends to revolve the dome on its seat. The dome is held down, yet so as to be free to turn, by the setting ring C. The ring has ratchet teeth inside so that it can only be turned in one direction, namely that tending to wind up the coil spring.

The striker F, which carries the cap, is in the stem of the fuze; it is actuated by the spiral spring surrounding it. It is held down by the locking-bolt V, actuated by the spring W, which tends to withdraw it outwards. The locking-bolt is prevented from moving outwards and unlocking the striker by the wall of the setting-ring, against which it abuts; when the hole O comes opposite the locking bolt the latter is free to fly out, allowing the striker to fire the fuze.

Before loading, the hole O is closed by the milled-headed screw S.

The spring constantly tends to unwind and revolve the dome, but is prevented from doing so by the worm J which engages with the latter. It is only as this worm turns under the action of the vane that the dome is allowed to revolve.

Thus in this fuze the action of the mechanism is assisted by the coiled spring.

To set the fuze, the dome and setting-ring are turned in the direction allowed by the ratchet till the hole O is at a given distance (corresponding to a given number of turns of the shell in flight) from the locking bolt.

During flight the worm rotates and allows the dome to turn back again till the hole comes opposite the locking bolt and the fuze fires.

The Semple Tracer.

For some years past the American artillery have been using "tracers" with all coast defence shell, and they have now ordered 10 per cent of their field shell to be fitted with them. The tracer may now therefore be said to have invaded the domain of field artillery.

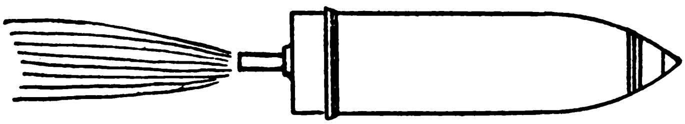
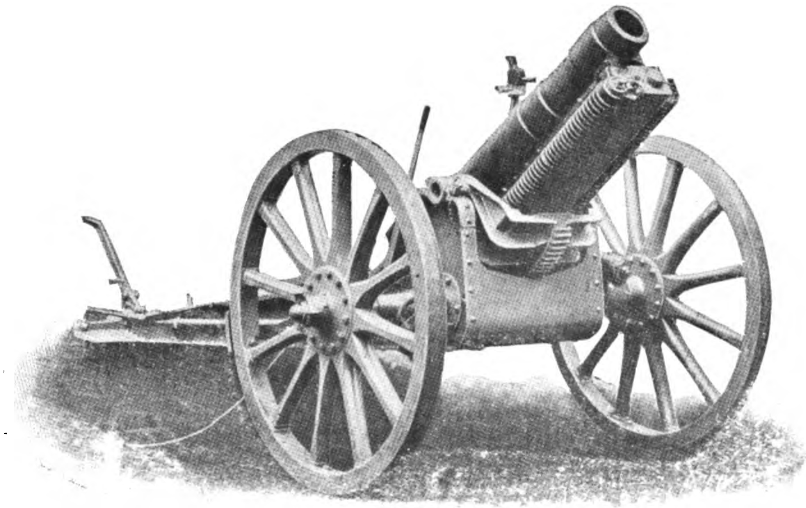


FIG. 76.

It consists simply of a metal-cased firework, about 2 inches long by ½ inch in diameter, screwed on to the base of the shell. This burns during flight, so that when firing at night the trajectory of the shell is plainly marked by a luminous trace. This enables the battery commander to see where the shell has gone to, and to distinguish his own shell from those of other batteries. Therefore so long as the target is visible the battery commander will be able to range on it at night. This may conceivably be of great use under certain conditions, as in the deliberate attack of an entrenched position, when the enemy's works are lighted up by projectors or star shell. The tracer does not betray the position of the battery from which it is fired, as the small point of light given by the illuminating composition is invisible from the front, being concealed by the body of the shell.

Attempts have been made to manufacture smoke tracers for use by daylight, but the amount of composition required to give a good trail of smoke is so large as to constitute a serious addition to the weight of the shell.

The tracer is a small and inexpensive addition to a field shell, and, in view of the increased tendency to carry out attacks on positions by night, necessitated by the power of the modern rifle, it is quite possible that it may be extensively adopted for field artillery.



KRUPP 4·7″ Q.F. HOWITZER.
1904.

CHAPTER XIX.

THE Q.F. FIELD HOWITZER.

Definition.

A field howitzer is a gun capable of throwing a heavy shell at angles of elevation up to 45%, and capable of being drawn at a trot by a six-horse team.

In practice these requirements, as worked out by the leading gun-makers, are satisfied by the following conditions:—

Weight of howitzer and limber, without gunners...	35 to 40 cwt.
Weight of shrapnel or H.E. shell ...	35 to 45 lbs.
Maximum muzzle velocity	1000 fs.
Calibre	4.2″ to 4.7″
Rate of fire	4 rounds per minute.
Recoil of howitzer on carriage ...	3 to 4 feet.
Length of howitzer	12 to 15 calibres.

Besides the field howitzer proper, there is also in existence a type known as the heavy field howitzer, with a calibre of about 6 inches, weighing some 60 cwt. behind the team. This is not a true field gun, but rather a siege gun or gun of position. A good specimen of this type is the Schneider-Canet howitzer described in Part IV.

Tactical Employment of the Field Howitzer.

The special features of the field howitzer, which differentiate it from the field gun, have been developed to suit the purpose which it is intended to fulfil.

A field howitzer serves two purposes—

1. To convey a heavy shell, charged with high explosive, to a given distant point.
2. To deliver a shower of effective shrapnel bullets, striking downwards at a steep angle of descent into an enemy's entrenchments or behind his gun-shields.

As regards the first point, the striking velocity of the H.E. shell is a matter of minor importance. The great thing is to get the shell to the desired point with as little effort as possible. And this is effected with a short gun and a small charge by using angles of elevation up to 45°.

As regards the second point, the question is more complicated. The striking energy of the bullets must not be below the 60 foot-pounds limit fixed in Chapter XXIV. Yet the muzzle velocity obtained from a short howitzer is low, and the striking velocity lower still. The difficulty is met by artificially increasing the bullet velocity by the use of a heavy driving charge in the shrapnel, and by using heavier bullets than are employed in field guns. This will be further considered under the heading of Howitzer Shrapnel Fire.

THE HOWITZER.

Construction.

The charge of smokeless powder employed in a howitzer rarely exceeds one pound, and the pressure in the chamber does not rise above 10 tons. The strain upon the metal is therefore not very severe Moreover, the length of recoil possible in a howitzer is limited to about 40″, as otherwise the breech would strike the ground when firing at high angles. It is therefore necessary to keep down the recoil-energy by putting as much weight as is available into the howitzer itself. (See Chapter on Recoil.) A field howitzer is therefore as a rule heavier than is necessary to stand the strain of explosion, and has a considerable surplus of strength in hand. This does not apply to rear-trunnion howitzers, with which a longer recoil is obtained.

Calibre.

The weight of the howitzer and carriage is, broadly speaking proportional to the muzzle energy. Now, if the muzzle energy be determined by fixing the weight and extreme range of the shell, the calibre may vary accordingly as a long slender shell or a short stumpy one is adopted. If the weight of the shell is to be 35 lbs., the calibre may be anything between 4″ and 4.7″. The 4″ shell will range further with the same muzzle energy, but, being longer, it will be more difficult to keep steady than the 4.7″ shell, and it will require a sharper twist of rifling. The best calibre for a 35 lb. shell has still to be determined. But hitherto it has been found that in most cases a short thick shell shoots better than a long thin one, and this is a consideration which has to be balanced against the longer range of the 4″ shell.

Rifling.

The accuracy of fire of a howitzer depends to a great extent upon the rifling and the driving band. Very little is definitely known as to the determination of the best possible angle and shape of groove for a given projectile, and the design of the rifling of a new howitzer is largely empirical. The difficulty lies in the fact that the shell has to change direction in flight through a large angle, since the sum of the angle of elevation and the angle of descent often exceeds a right angle. If therefore the twist of the rifling is excessive, having regard to the length of the shell, then the shell will tend, after passing the vertex of the trajectory, still to keep its original position with the nose pointing upwards, and will come down more or less sideways. If, on the other hand, the twist be insufficient, then as the velocity increases during the fall of the shell from the vertex, the shell will become unsteady and wobble or even turn over.

It is therefore of great importance that the twist of the rifling be such as exactly to suit the design of the shell.

Of the two evils, too much or too little twist, the consequences of the latter must at all costs be avoided. We therefore find that howitzers are usually rifled with a sharper twist in proportion to length of shell than guns.

Breech Mechanism.

Extreme rapidity of action is not essential, as the heavy ammunition cannot be handled as quickly as that of a field gun. The principal object of the designer is therefore to produce a strong and simple breech mechanism occupying little lateral space between the brackets of the carriage. The eccentric screw becomes rather cumbrous when applied to a large calibre, and the choice lies between the wedge and the swinging block, the former being usually preferred on the score of simplicity.

Sights.

The howitzer sight proper is the dial sight described in Chapter XI., which is in effect a theodolite mounted on a pedestal attached to the cradle. This sight enables the howitzer to be layed for direction by the use of a distant aiming point, and for elevation by a clinometer which is embodied in the sight. It also automatically corrects the error due to difference of level of wheels.

Besides the dial sight, a howitzer is fitted with plain open sights, usually of the arc pattern, for direct laying on emergency.

Firing Gear.

This is of the ordinary percussion type, of simple pattern. A trip-lock is usually preferred. In this lock the main-spring is not in tension till the firing-lever is pulled; the effect of pulling the lever is first to draw back the striker against the spring and then to release it. The lock does not require to be cocked, and can be fired again after a mis-fire by a fresh pull of the lever.

THE CARRIAGE.

Owing to the great weight of the shell as compared to the howitzer, the recoil energy is greater than that of a field gun, requiring a heavy carriage to stand up to it. Thus if we suppose a howitzer firing a 40 lb. shell with a M.V. of 1000 fs., then on calculating the recoil-energy we find that this is over 10 foot-tons, or double that of a Q.F. field gun. And if the permissible recoil of the howitzer on its carriage be 3 feet, then the average pull on the piston rod of the buffer is 3.3 tons. To resist these severe strains the carriage of a howitzer requires to be considerably stronger than that of a gun.

Steadiness.

It is now generally recognized a shielded field howitzer must be capable of being employed on emergency as a gun; that is, of coming into action in the open and using direct fire. Accordingly, it should be steady when firing point-blank with full charge. In view of the high recoil-energy, this condition is not easy to realize, and field howitzers are sometimes designed to be steady point-blank with the second charge only. This compromise saves the weight of a long trail, and so renders the howitzer more efficient when used for its own proper work.

Length of Recoil.

The difficulty of applying the long-recoil principle to howitzers lies in the short distance between the breech and the ground.

If the howitzer is suspended in the ordinary way, with the cradle trunnions at or near the centre of gravity, then at high elevations the space under the breech available for recoil does not exceed 18 inches. This means that the force of recoil, say 10 ft.-tons, has to be absorbed in a recoil of 1½ feet, producing a pull on the carriage of 6⅔ tons. At low elevations this pull is sufficient to lift the wheels off the ground.

Controlled Recoil.

There are several ways of getting over this difficulty. The method used by Messrs. Ehrhardt and others is known as *controlled recoil.* This has been fully discussed in Chapter XV.

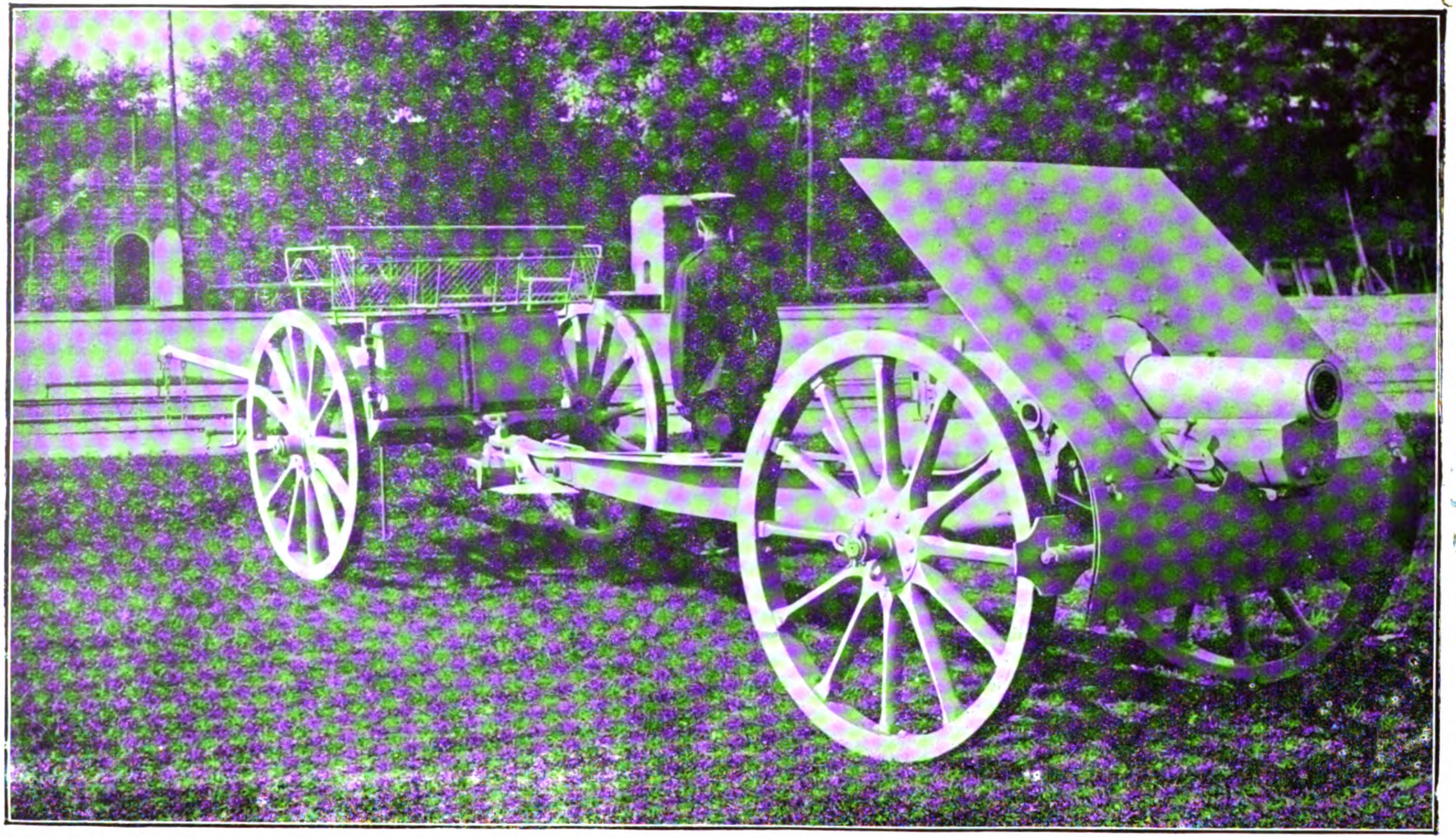
Controlled recoil secures perfect steadiness of the carriage in firing. The objection to it is the heavy downward strain upon the carriage at high elevations, which has to be met by a proportionate increase of strength and weight of the carriage.

Rear Trunnions.

It is not possible to get increased length of recoil by setting the howitzer very high up, as this would render it unsafe to travel. But by setting the trunnions at the rear of the cradle we at any rate prevent the breech from coming nearer to the ground when the howitzer is elevated. With a 4 ft. 8-inch wheel and straight axletree the height of the axis cannot well be less than 3 ft., probably more. This in practice allows of a recoil of 48 inches, giving a strain on the carriage of 2½ tons only. This length of recoil, with a 9 ft. trail is sufficient to keep the carriage steady on firing.

There are several drawbacks to the rear-trunnion method. The total weight of howitzer and cradle is say 10 cwt. If this is supported on trunnions at one end and elevated at the other, then the elevating number has to lift a weight of 5 cwt. by turning a hand-wheel. This would require a powerful and therefore a very slow gear. To relieve the gunner of some part of this heavy labour a balance spring is fitted under the front of the cradle, which takes most of the weight. But this is not a very satisfactory arrangement, since the higher the howitzer is elevated the weaker the spring becomes. To make the spring take any considerable part of the weight at high elevations, it must take more than the weight of the howitzer at low elevations, so that the howitzer is then pressed upwards against the elevating gear by the spring. That is, when the howitzer is fired at a low elevation its weight is resting on the spring, which gives to the shock of discharge, allows the muzzle to dip, and so affects the accuracy of the shooting.

There are several other objections to the rear-trunnion method. At full elevation the weight of the howitzer is as high as the top of the wheels, and there is a risk of overturning when firing on bad ground. The rear trunnions do not give the same lateral steadiness as trunnions in the ordinary position, and errors of direction are liable to result. Moreover at high elevations the trail lift is considerably increased.



SCHNEIDER 4.2″ FIELD HOWITZER.
1909.

Messrs. Krupp have adopted the rear trunnion system with recoil of 48 inches and claim to get very fair shooting with it. Their 4.7″ howitzer on this system has been adopted by several foreign powers.

Messrs Ehrhardt and Schneider prefer the controlled recoil method, and Messrs. Cockerill use a combination of rear trunnions and controlled recoil. But none of these methods can be considered entirely satisfactory. Differential recoil, swinging recoil, and the revolving cranked axletree (page 140) have yet to be tried before the question of the best form of howitzer carriage can be finally settled.

Traversing Gear.

Here the difficulties to be overcome are the same as in the Q.F. field gun-carriage, with an important additional complication. In the field gun-carriage the gun traverses above the trail; in the howitzer carriage the howitzer must traverse between the trail brackets. That is, we must find room between the brackets for the howitzer to traverse not only in the firing position but in the extreme position of recoil, some 48″ behind the firing position. The swinging pivot (page 141) is particularly objectionable in a howitzer. The French system of traversing the whole trail and howitzer along the axletree, pivoting about the point of the trail, is objected to on account of the weight to be moved; but this, in combination with a buffer and compressed air running-up gear under the howitzer, is perhaps the lightest form of carriage as yet devised.

Elevating Gear.

The large angle through which the howitzer has to be elevated prevents the application of the tangent elevating screw. In the English 5″ howitzer elevation is given by a screw working on a bell-crank lever attached to a trunnion. But with a Q.F. howitzer this would only be admissible if two buffers were disposed symmetrically on either side of the howitzer so that the pull on the cradle would take place in the plane of the trunnions, thus preventing any torsional strain on the trunnion on recoil. The gear usually fitted is a toothed arc under the gun with which a worm wheel on the elevating spindle engages. All modern howitzers have a quick-motion elevating lever or gear by which the howitzer can be swung into a horizontal position for loading and then returned to its former elevation.

Buffer and Springs.

These have to be large and strong, in order to take up the high recoil energy in the short limits of recoil which can be allowed. The springs must moreover be strong enough to lift the weight of the howitzer to the firing position at extreme angles of elevation, The return to the firing position is facilitated by fitting a controlled running-up valve in the piston, which allows the liquid in the buffer to pass more freely during running up. The hydro-pneumatic running-up gear has recently come into favour; a successful instance of its application is the Creusôt howitzer described in Part IV.

The Spade.

This must be of large area in order to hold the carriage against the severe recoil. It is made as wide and as shallow as possible. There

is never any difficulty about a howitzer spade gripping, as the strong downward pressure forces it into the ground at the first round.

The Shield.

To enable a field howitzer to be used as a gun on emergency, it is usually fitted with a shield, the 3½ mm. shrapnel-proof thickness being preferred. In some equipments a supplementary shield is fixed to the cradle to close the large opening in the shield which is necessary to allow the howitzer to be elevated to 45 degrees.

THE LIMBER.

Supposing that the total weight behind the team without gunners is not to exceed 40 cwt., and that the weight of the howitzer in action is to be 24 cwt., this leaves only 16 cwt. for the limber and ammunition. Even supposing that 3 rounds of ammunition weighs only 1 cwt., which is a low estimate, then 18 rounds will weigh 6 cwt., which is as much as we can expect a 9 cwt., (empty) limber to carry when weighted in addition with 3 gunners, kits, and stores.

THE WAGON.

Taking the necessary supply of ammunition for one fighting day at 120 rounds for a Q.F. howitzer, then each howitzer mnst have 102 rounds following it in wagons. Suppose each wagon to carry half its total weight of ammunition, besides gunners, and we have a total of 10 wagons per battery. Or if the wagons are to weigh only 38 cwt., then 12 wagons will be required.

And, in view of the limited supply of ammunition and small number of gunners carried by the gun-limber, six at least (if not all) of these wagons should be capable of keeping pace with the howitzer and accompanying it in action.

THE HIGH-ANGLE HOWITZER.

Some R.M.L. howitzers were constructed ro fire at all angles of elevation up to 70 degrees.

The power of firing shrapnel at these high angles is very useful; the bullets descend vertically, and the spread due to the angle of opening even enables them to take walls and parapets in reverse. The complication entailed by the use of varying charges can be got rid of, and fixed ammunition can be used.

There are two objections to high-angle howitzers. One is the extra weight of the carriage. which has to be strong to take up the short recoil. For the length of recoil is limited by the space between the breech and the ground when the howitzer is in the firing position.

The other objection is the extreme difficulty of getting a high-angle howitzer to shoot accurately. From what has been said about the difficulty of suiting the rifling to the shell for an ordinary howitzer, it will be understood that the difficulty in this case is much increased. For as the shell rises to the vertex of the trajectory its forward velocity falls off almost to nothing, while the spinning velocity of the shell is but little diminished. This mean that the shell does not turn over at the vertex, but begins to fall base first. But for its being flat at one

end and pointed at the other it might continue to fall in this fashion and come down in the same position in which it ascended. As it is, however, the shell overbalances at some moment during its descent, as the velocity increases and the air resistance becomes sufficient to overcome the gyroscopic effect of the spin. If this over-balancing always took place at the same moment, it would not affect the accuracy of the shooting. But the exact moment of overbalance is dependent on minute causes which cannot be estimated exactly, and the practical result has hitherto been that it is no more possible to predict where a high-angle shell will fall than to say in which direction a spinning top will roll when it runs down.

It is possible that the overbalancing difficulty may be got rid of by the use of special forms of shell, such as a "tadpole" shell with heavy head and long taper base. Up to the present, however, nothing has been effected in this direction. And even if the ballistic difficulty be got over, we have still a source of error which it is impossible to contend with, namely, the wind-deflection to which a shell rising high into the air is exposed.

These considerations have led to the high angle howitzer being for the present abandoned.

The Mountain Howitzer.

This will be described under the heading of Mountain Guns.

AMMUNITION.

Though a howitzer fires both high-explosive and shrapnel shell, it is most desirable that the shooting with the two different projectiles should be the same. Supposing the range found with H.E. shell, it would be a serious disadvantage to have to range over again on changing to shrapnel.

Now the ideal shrapnel is a case containing the maximum weight of bullets in proportion to the total weight of the shell, while the ideal H.E. shell is a thin case—a "mine" or "torpedo" shell—containing the maximum weight of high explosive. As the specific gravity of lyddite, for instance, is 1.6, while that of mixed metal is 9, it is clear that two shells of the same weight, one filled with lyddite and the other with bullets, must be of very different dimensions, and must shoot very differently.

Next comes the question whether the high explosive or the shrapnel shell is to be considered the more important nature of ammunition For the field howitzer, preference is usually given to the shrapnel. Accordingly, the H.E. shell is made to conform as nearly as possible to the shape of the shrapnel. The thin-walled mine shell, containing perhaps 10 lbs. of T.N.T. or lyddite, has to give place to a thick-walled heavily-built shell, affording space for only 1 or 2 lbs. of explosive. Even so it is hardly possible to make the H.E. shell as short as the shrapnel, and the shooting has to be adjusted by making the shells with heads of different shapes, using a longer ogive for the long shell, so as to make the two shoot as nearly as possible alike.

Howitzer Shrapnel.

A field gun shrapnel must have a small angle of opening, so as to sweep the greatest possible depth of ground. But a howitzer shrapnel comes down at a sharp angle, so that the sweeping effect hardly enters into the question. The object is rather to make bullets strike as nearly as possible vertically downwards than to cover a large area of ground. Accordingly a howitzer shrapnel is designed to give a wide angle of opening. Suppose the angle of descent 50° and the angle of opening 24°, then the lowest bullets of the cone will strike downwards at 62°, or only 28° from the vertical. The wide angle is secured by putting a proportion of the bursting charge in the central tube, by putting a liberal allowance of coarse smoke-producing powder among the bullets, and by coning the diaphragm so as to spread the bullets outwards.

Driving Charge.

A howitzer shell, even with full charge, travels at a low velocity, and this is further reduced when the smaller charges are used. In order to make the bullets effective it is therefore necessary to increase their velocity by the use of a heavy driving charging behind them, as much as ¾lb. of powder being used.

Owing to the long time of flight, the effect of any irregularity in the burning of the fuzes is to give a greater error in the point of burst of the shell than is the case with field guns. To compensate in some measure for this, howitzer shrapnel bullets are usually made heavier than those used in field gun shrapnel.

Weight of Howitzer Shrapnel Bullets.

The following sizes are given by General Rohne—

German Light Field Howitzer			48	to the pound.
Krupp 4.1″	"	...	35 or 29	"
Krupp 4.3″	"	...	29	"
Krupp 4.7″	"	...	34 or 29	"
Krupp 5.8″	"	...	35 or 29	"
English 5″ B.L.	"	...	16 and 50	"

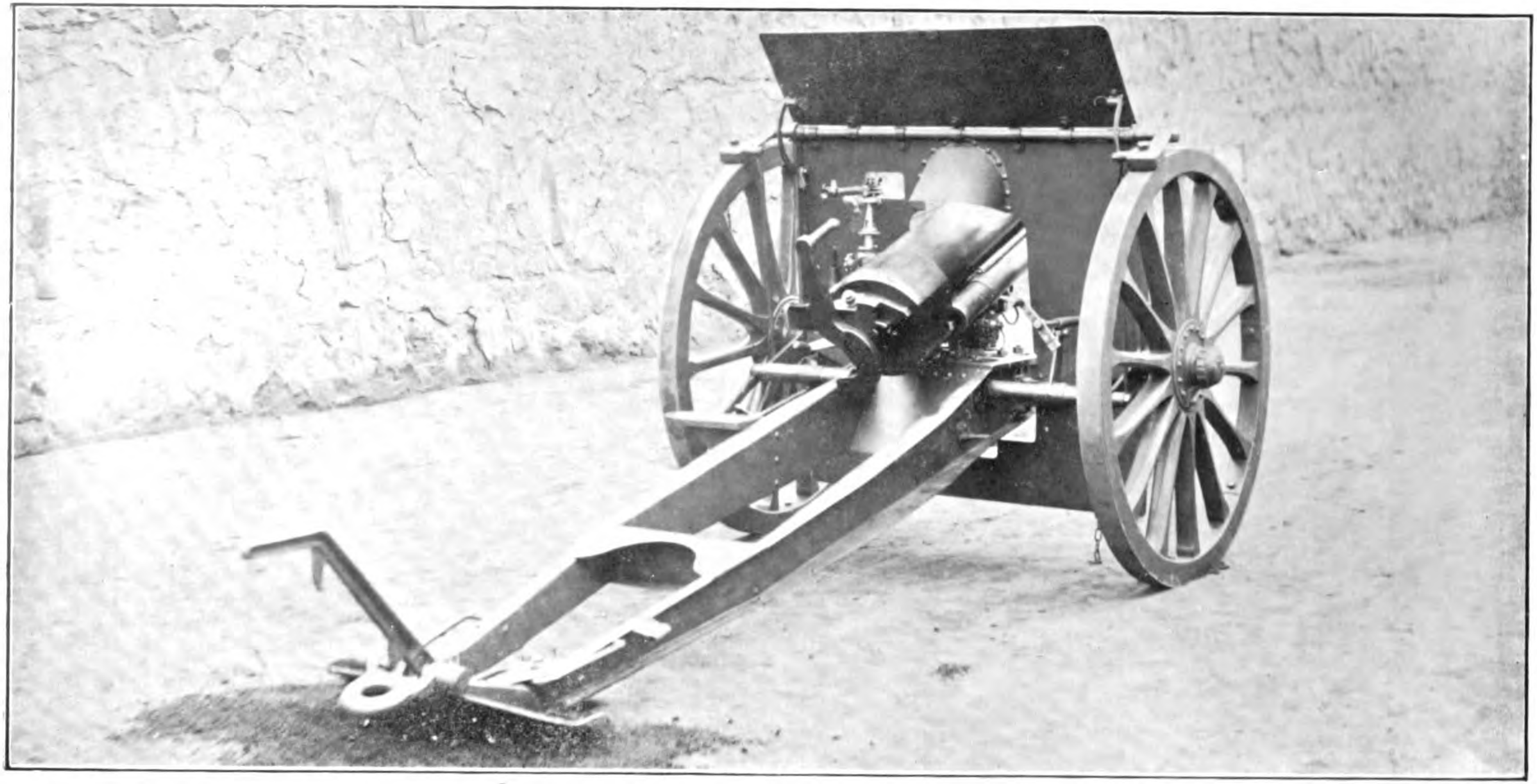
The present tendency is to increase the weight of the bullets, and 16 grammes or 29 to the pound seems to be the favourite size.

Howitzer High-Explosive Shell.

As already explained, the walls of the shell have to be made very thick in order to bring up the weight without unduly lengthening the shell. It is further desirable to make the shell of hard and somewhat brittle steel, of high tensile strength. The object of this is in the first place to develop as high a pressure as possible inside the shell before it bursts (thus ensuring complete detonation of the burster) and in the second place to provide a large number of effective man-killing fragments. The harder the metal the less force is wasted in local action, that is to say in tearing the metal into small useless splinters which only fly a few yards. A shell of soft copper would, if detonated properly, be broken up into minute fragments.

Howitzer Fuzes.

The time fuze for shrapnel must be as accurate as it can be made, the object of the practice being to burst the shell above the target.



COCKERILL 4.7″ HOWITZER.

1904.

This is necessitated by the wide angle of opening. The ignition arrangement further requires to be sensitive, otherwise it will not be set in action when the shell is fired with a reduced charge. Quick setting is not so essential as in a gun fuze, and a safety pin to secure the ignition arrangement when travelling is therefore admissible.

The two types of fuze best adapted to overcome the difficulty as to sensitive ignition are the centrifugal fuze and the bolt fuze. In the latter the fuze is unlocked by a piston in the base of the shell, which is driven in by the pressure of the powder-gases. Fuzes of both these types are already in the Service, and are described in the Treatise on Ammunition.

The percussion fuze is easier to design, since with a sharp angle of descent the check of velocity on impact is sudden and violent. The difficulty is not so much in the fuze proper as in the cap or detonator which is to communicate the explosion to the lyddite. Progressive detonation (page 159) would appear to be the most suitable method

A fulminate fuze is dangerous both on account of its liability to explode in the limber, and of its tendency to explode prematurely with the shock of discharge. The first objection can be got over by carrying the detonator separately and only inserting it just before loading; but the second is more difficult to overcome. The most promising device for this is the air-space fuze, described in the chapter on Field Gun Ammunition, in which the primer is kept separate from the fulminate detonator till the instant of impact.

In some Continental equipments this difficulty has been avoided by discarding picric acid as a burster and substituting ammonal or gun-cotton powder, which can be detonated without a fulminate primer.

The efficiency of high-explosive shell in destroying cover is much increased by the addition of a delay action to the fuze, which enables the shell to penetrate for some distance before bursting.

Howitzer Cartridges.

Case ammunition is always employed in Q.F. howitzers, not only on account of quicker loading but because it secures more regular ignition of the charge and dispenses with the complications of obturation and of firing by friction tube. The cartridge case has a removable cover (usually of papier maché) and contains a charge of smokeless powder made up in four or more portions of different weights.

The reason for using different charges is as follows—

Supposing that with a full charge and elevation of 45° the range is 7000 yards, then if it be required to fire at at 3000 the elevation will be only some 15° and the angle of descent 18° or so, which is insufficient for searching entrenchments. But if a ¼ charge be used the angle of elevation will be 40° and the angle of descent 45°. To get a sharp angle of descent at all ranges between 2500 and 7000 yds. it is therefore necessary to have at least 4 different charges, each giving a different muzzle velocity and requiring a separate range table of its own. The Krupp field howitzers, for instance, have 6 charges.

Gun-cotton powder is found unsuitable for howitzers, as it gives very irregular pressures when a small charge is burnt in a large chamber. Continental nations which use gun-cotton powder for guns have therefore adopted nitro-glycerine powder for howitzers.

Driving Band.

Since separate case ammunition is used, the case cannot be relied upon to determine the position of the shell in the chamber, as in a field gun. The driving band has therefore to be made with a long cone, so that it will stick in the rifling when rammed home, and will not drop back even when the howitzer is elevated to 45 degrees.

Probability of Hitting.

A howitzer range table gives the dimensions of the 50% length, breadth, and height zones in the same manner as for a gun, and the probability table is used in the same way.

Example.

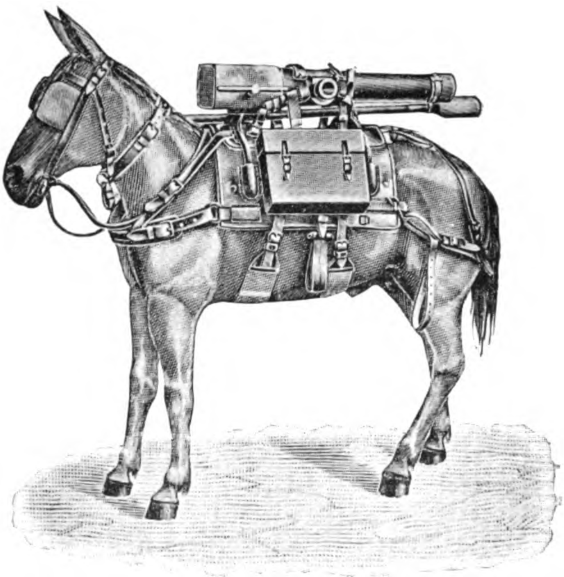
How many rounds of lyddite shell from the 5 inch B.L. howitzer with full charge will be required to make one hit on a field casemate 20 yards wide and 10 yards deep at 3500 yards, presuming the range and line already found?

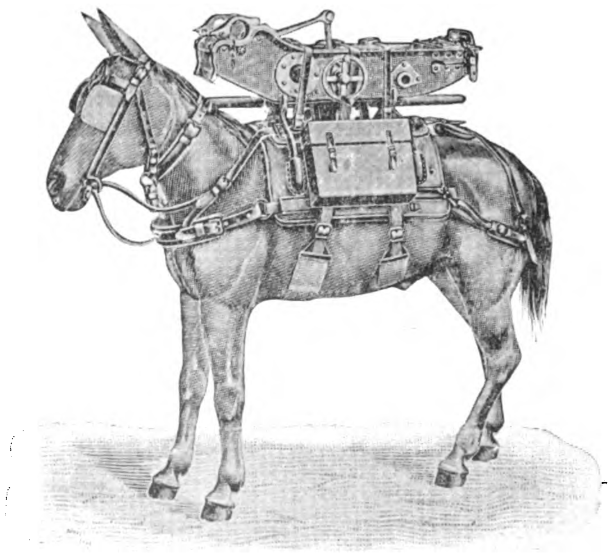
From the range table, the breadth of the 50% zone is 4.74 yards, depth 32.6 yards. Then the 100 per cent. zones are 4 times as large. 4 times 4.74 is 18.96; therefore all the shell will be correct for line.

As regards depth, $\frac{10}{33} = .3$ nearly; opposite to factor .3 in the probability table we find 16 per cent. Therefore all the shell will be correct for line, and 16 per cent. of them correct for range.

Therefore, after range and line have been correctly found to the centre of the target, we may expect to obtain 16 per cent. of hits, or 1 hit every 6 rounds.

This assumes ideal conditions for practice, and absence of wind or other disturbing factor.





KRUPP MULE EQUIPMENT.

1904.

CHAPTER XX.

THE Q.F. MOUNTAIN GUN.

The duty required of a mountain gun is to support the infantry in attack, defence, or encounter over ground inaccessible to field guns. It is merely a field gun sufficiently mobile for mountain transport.

Weight and Dimensions.

The weight and dimensions of the mountain gun are restricted by the following considerations:—

1. The whole equipment has to be carried on pack mules.
2. The average load which an ordinary mountain battery mule is able to carry is about 280 pounds, including 65 pounds of saddle and equipment. A few specially-selected gun mules can carry about 40 pounds more, or 320 pounds. In Spain and Italy, where exceptionally fine mules are available, some of the mountain battery loads amount to 375 pounds.
3. For work on a hillside, the loads must be short, the length being limited by that of the neck of a mule. If possible, no part of the equipment should be more than 4′ 6″ long.
4. The equipment must therefore be subdivided into component parts such that no part weighs more than 320 — 65 or 255 pounds, and these parts must be so designed as to be quickly assembled.
5. The number of parts into which the equipment may be subdivided is either 4 or 5. Our British mountain batteries have 5 gun and carriage mules, and yet they pride themselves on coming into action and firing the first round within one minute. Continental nations however mostly prefer to divide the equipment into 4 parts only, and they use rather heavier loads than we consider consistent with activity on the hillside.

Power of Gun.

If this were only limited by the total weight of the equipment, we should be able to obtain a gun half as powerful as a field gun. On a 5-mule basis the total weight of gun and carriage carried amounts to 10¼ cwt., or more than half the weight of a field gun. But the power obtainable is limited in practice by the weight of the gun itself. In B.L. mountain equipments the difficulty has been got over by carrying the gun in two parts which are screwed together on coming into action.

Jointed Guns.

The 7 pr. of 400 lbs.—the original "screw-gun"—and the 10 pr. B.L. were two thoroughly serviceable equipments, and demonstrated the perfect practicability of carrying the gun in two pieces. But when it comes to making a trunnionless Q.F. gun, with guides to slide in a cradle, in two parts, practical difficulties arise. The solution now generally adopted is to divide the gun at the base of the cartridge, not half way down the bore. The breech-ring and breech-block are carried separately, thus reducing the gun-load. Two modern guns on this principle, the Vickers Maxim and the Schneider-Danglis, are described in Part IV. The latter gun fires a 14.3 lb. shell with M.V. of 1150 fs., giving a muzzle energy of 130 foot-tons. The same gun would fire a 12 lb. shell with M.V. of 1350 fs.

The Krupp Sleigh.

The difficulty about the guides is got over by the use of the Krupp "sleigh." This is, in effect, a sliding cover to the U cradle. The sleigh, not the gun, slides on the cradle guides, and the gun, when put together, is dropped into recessed blocks on the sleigh and secured by a lug and transverse key. The sleigh is never separated from the cradle, and serves to protect the guides when travelling.

Subdivision of Equipment.

When the gun is in two pieces the equipment naturally divides itself into five parts, namely the two gun-loads, the cradle, trail, and axletree and wheels. When a very long jointed trail is used, as in the Krupp Q.F. mountain equipment, the point of the trail is carried with the wheels, which form a light load. In addition to this the folding shield, with one box (or rather two half-boxes) of ammunition forms a sixth load. The shield need not however be brought up till after the gun has opened fire.

Calibre.

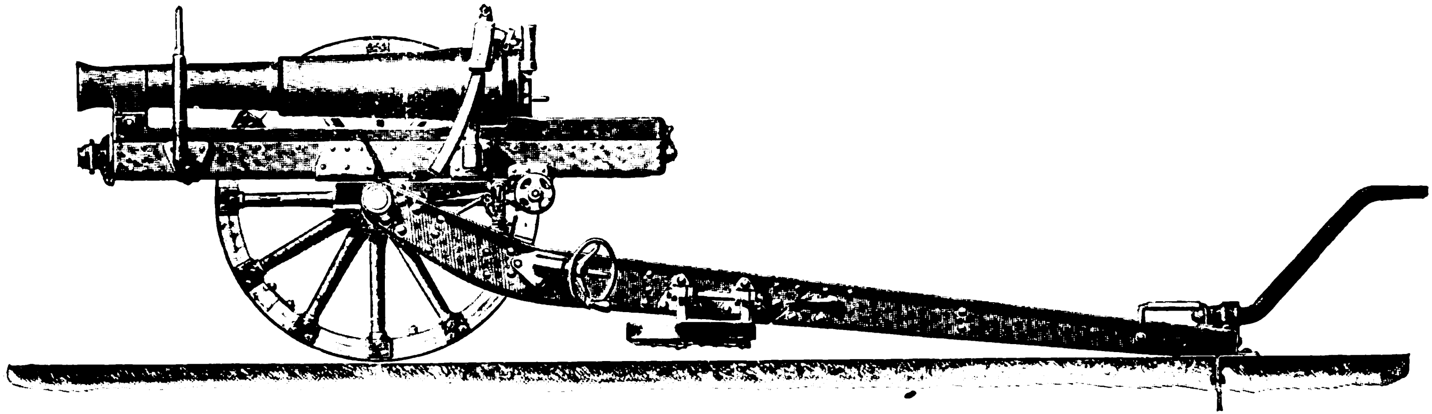
To get good ballistics, the calibre of a mountain gun ought to be reduced proportionately to the reduced weight of the shell. But here the limitation of length steps in—the length of the gun without the breech-ring may not exceed 4 ft. 6 in., therefore the calibre must be large to give the necessary amount of pressure on the base of the shell. Hence all Q.F. mountain gun equipments are made to the 75 mm. or 2.95 in. calibre.

Construction of Gun.

The maximum length of each gun-load should not exceed 4 ft. 6 in. To get the maximum power out of this short length, the gun is made with an enlarged chamber to take a coned or bottle-necked cartridge, and for the same reason the conical or ogival swinging breech-block is preferred. The Nordenfelt eccentric screw also gives a short and well-protected breech action.

Sights.

The sights must be of simple pattern, that will not be disabled when a mule rolls down the khud. Pedestal sights, rocking bars, and independent line of sight are practically out of the question. A plain bar or arc-sight, with a panoramic attachment, is therefore preferable.



KRUPP 75mm. MOUNTAIN GUN.

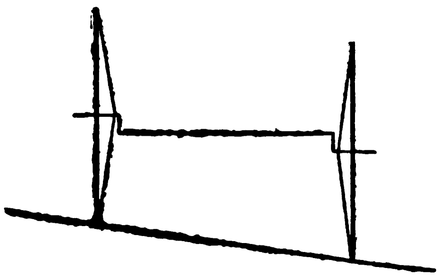
1904.

At the same time, since it is the exception to find a level emplacement available, it is most desirable that the sight-socket should be capable of being cross-levelled to compensate for difference of level of wheels.

The Krupp all-round sight for mountain guns is described in Part IV.

Cranked Axletree Arms.

It is suggested that the difficulty of fitting a mountain gun with reciprocating (that is, cross-levelling) sights may be evaded by tilting the whole carriage.



Thus in the accompanying diagram the left axletree arm is cranked up and the right arm down, so that the carriage stands level on a left-to-right slope. Now if the axletree be revolved by worm gear through 180°, the carriage will stand level on a right-to-left slope; and the carriage may be levelled, by turning the axletree, for any slop ebetween these two extremes. On level ground the axletree will be revolved through 90° from the position shown; both wheels will then be level, but one will be some inches in advance of the other. This device has not yet been applied in practice.

Construction of Cradle.

In the original Vickers-Maxim equipment the cradle surrounds the gun, which is slipped into it on coming into action. In the Krupp and Ehrhardt equipments the cradle is a closed trough or box under the gun, with vertical trunnion, containing the buffer and running-up springs as in the field gun equipments, but with the addition of the sleigh already described.

The Trail.

To keep a light mountain gun steady, the trail must be fairly long, Three patterns are in existence. The Vickers-Maxim trail (1908 pattern) folds into three; the Krupp trail is in two pieces, carried separately; and the Ehrhardt trail is Y shaped, the stem of the Y being hinged to fold up for transport. All these trails are about 7 feet long, and with two big mountain gunners kneeling on the seats (which are close to the ground) give an absolutely steady carriage.

The Spade.

This is similar to that used on field guns, but proportionately small in size. It is sometimes made folding, so that it need not be used on rocky ground.

The Wheels.

These are usually of wood, and from 2′ 8″ to 3′ 4″ in diameter.

Elevating Gear.

This is a plain screw, set near the horizontal axis so as to reduce its length as far as possible.

Traversing Gear.

The cradle traverses on its vertical pivot through about 3 degrees each way.

Shaft Draught.

On the Continent a mountain battery expects to do most of its travelling on roads. A light pair of shafts are carried which can be attached to the trail so that one mule, or two mules tandem, can pull the gun instead of carrying it.

Thus the mountain guns which General Kuroki took with him on his march from the Yalu across the mountains to Liao Yang travelled for the most part in draught. His mules and ponies were far inferior to the sturdy animals used in our service, and most of them would probably have succumbed if they had had to carry their loads all the way. As it was, they got through without much difficulty.

Shield.

A shield high enough to give cover to the detachment kneeling, and bullet-proof up to short ranges, weighs from 80 lbs. to 1 cwt. It is hinged to fold up for convenience of carrying. The ordinary pattern of gun-shield, which merely fills up the space between the wheels, affords insufficient protection, and a shield extending above and outside the wheels is preferable. A separate shield for the ammunition numbers is usually provided. See Part IV.

The Saddle.

As stated above, the average weight of the saddle and equipment is, in our service, about 65 lbs. Gun-makers, whose experience of mules is limited, sometimes try to save weight by using a light saddle. This is however false economy, as if the saddle is too small or too short it rocks under a top load, and is much harder on the mule than a full-sized saddle.

The lower the load can be carried, the better it travels; thus ammunition loads, which are carried below the level of the arch of the saddle, may be as much as 50 lbs. heavier than top loads.

Attempts have frequently been made to construct a universal saddle, so that any portion of the equipment may be loaded on any mule. This ideal is very difficult to realize, owing to the varied shape of the loads, and the result is usually a saddle which fails to carry any load to the satisfaction of the animal beneath it.

Existing Q.F. Equipments.

Three principal equipments are in use, namely the Vickers-Maxim, the Krupp, and the Ehrhardt. Besides these, all the principal gun-makers have mountain equipments of their own. These are described in Part IV.

SCHNEIDER 75mm. MOUNTAIN GUN.
1909.

THE MOUNTAIN HOWITZER.

There has arisen of late a demand for a howitzer which shall fulfil the conditions laid down for a mountain gun, and shall be capable of throwing a shell weighing 20 to 25 lbs. with a steep angle of descent.

The construction of such a howitzer involves a new and interesting problem.

Let it be supposed that the weight of the shell has been fixed at 22.5 lbs. and the maximum range, with full charge, at 5000 yards. This will require a calibre of about 3.5 inches.

The calculation for the muzzle velocity is worked out on page 33. We find that a M.V. of 822 fs. will carry the shell 5000 yards with 38° of elevation. The energy will be 105 foot-tons.

If now we start with a howitzer in one piece weighing 210 lbs., this makes the weight of recoiling parts, including a sleigh, about 280 lbs., and the recoil energy 9.25 foot-tons. Taking the weight in action at ⅓ ton, and the trail length such as to give a 4 to 1 mechanical advantage, then, if the howitzer is to stand steady when fired without elevation, the recoil allowed must be 4.62 feet, which is impossible.

If we try a jointed howitzer weighing 420 lbs., then we get a recoil energy of about 5.3 foot-tons, requiring a recoil of 2.7 feet to keep it steady point blank. This is within practical limits.

The next difficulty is the impossibility of finding space for long recoil under a low mountain howitzer. Controlled recoil alone will not help us here; we must have rear trunnions and controlled recoil as well. Other alternatives are the revolving cranked axletree described on page 140, the differential recoil gear (page 133) and curved or swinging recoil (page 137.) Of these, the revolving cranked axletree would appear to offer the simplest and most practical solution. Fortunately in the case of a mountain howitzer there is no such difficulty in applying this principle as arises in the case of a field howitzer weighing 9 cwt. A Schneider mountain equipment on this system is described in Part IV.

CHAPTER XXI.

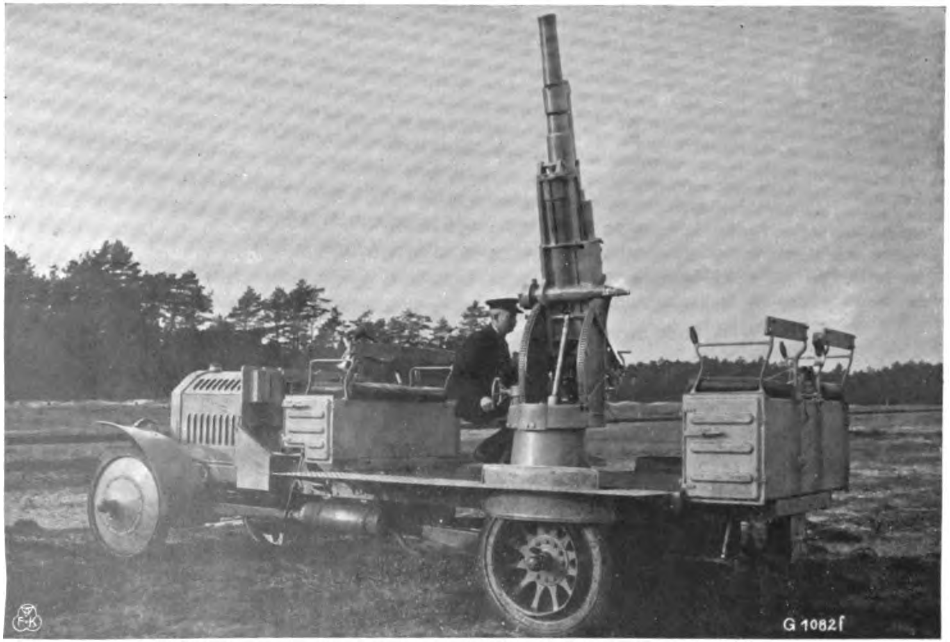
THE Q.F. BALLOON GUN.

Dirigible balloons are capable of making journeys of 500 miles and over without replenishing fuel. They will be used in war for strategical reconnaissance—that is, for discovering the positions of the enemy's armies and fleets—and also, to a less extent, for tactical reconnaissance. But this latter duty will be discharged principally by aeroplanes, which, unlike the great dirigibles, can easily be transported with an army in the field, and do not require a balloon-shed to shelter them.

It is important, then, to consider the means of fighting dirigible balloons and aeroplanes.

In the first place, we may attack them with air-ships of our own. There can hardly be any question of ramming or boarding, since this would involve the destruction of both parties. The attack must be made with projectiles, either dropped from above by the more agile ship, or fired from a gun. The gun must be of small calibre, since the explosion of a heavy charge would probably burst the balloon or rip up the planes of an aeroplane. It is considered that the danger from fire would be no greater than with the explosion engines already used. It has been suggested that compressed air or compressed hydrogen might be used as a propellant; but this, with the cylinders for carrying it, would weigh much more than an equivalent number of cartridges. The gun will only be used at short ranges, probably not exceeding 100 yards, since the ammunition supply is necessarily limited, and the chance of hitting at longer ranges, when both air-ships are in rapid motion, is small. A muzzle velocity of 300 fs., which would enable the shell to traverse the intervening space of 100 yards in little more than one second, will probably suffice. Roughly speaking, the shell must weigh not less than 3 lbs. if it is to be provided with a fuze and is to carry bullets or a high-explosive burster. That is, the muzzle energy of the gun will be 1.872 foot-tons. If the gun weighs 1 cwt., the recoil-velocity will be about 8 fs., and the recoil-energy $\frac{1}{10}$ foot-ton, which is not too much even for a two-seated aeroplane. If the gun be mounted without free recoil on a pivot fixed to the car of a dirigible balloon, the recoil-energy will be less, as the weight of the car will take up the recoil. It would seem possible to provide a gun of this type, complete with mounting, and 30 rounds of ammunition, at a total weight of 3 cwt. This is only the weight of two men, and a dirigible the size of the Patrie carries 12 men, while the latest Zeppelin can carry 24.

There is therefore no difficulty in arming a dirigible balloon with an efficient gun. But as regards the aeroplane the conditions are different: a second man must be carried to work the gun, and a



KRUPP 12-pr. BALLOON GUN ON TRAVELLING MOUNTING, 1909.

weight of 3 cwt. in addition would be more than the present type of aeroplane could carry. A larger type would have to be constructed, and this would be difficult to transport and to shelter, and difficult to start. It would seem that for the present the aeroplanist will have to be contented with a repeating rifle.

In the next place, we will consider the means of attacking air-ships from the ground. The ordinary field gun is practically useless for the purpose, since it is only capable of some 15° of elevation, and the trajectory, even at extreme range, does not rise above 1600 feet. The field howitzer, with its curved trajectory, is not suitable for hitting moving objects. A high-angle, high-velocity gun is required.

The weight and power of such a gun are limited by the conditions of its employment. Thus we shall have guns on permanent mountings for the defence of fortresses and dockyards, guns on naval pivots for use on ship-board, and mobile guns for use in the field. The two former types are beyond the scope of this book.

The weight of a field balloon gun is determined by that of the ammunition employed, and this depends upon the target and method of fire.

Dirigible balloons are of two types. The rigid type, such as the *Zeppelin*, consists of a framework of wood or aluminium, covered with an envelope, and containing separate chambers of hydrogen. The non-rigid or Parseval type is a gas-bag, possibly in three or more compartments, with an interior balloon called a ballonette. Each has a car suspended below it containing the engines and crew. An aeroplane is a light framework on which textile material is stretched, and to which the engine is attached. In firing at a balloon, the attack is directed principally at the gas-chambers or gas-bag, since the chance of hitting the framework or the car is small. The gas-chambers may be destroyed in three ways; by perforating them, bursting them by concussion, or setting them on fire.

Perforating a balloon by shrapnel fire is most unsatisfactory work. It is exceedingly difficult to get an effective burst, not only owing to the rapid motion of the balloon, but on account of the difficulty of locating the shrapnel burst with reference to it. And this difficulty is increased by the fact that the shrapnel must be burst so that it appears to be above the balloon; if the burst covers the balloon, unless close up, the bullets will all be below it. Cross observation is too slow, except at a captive balloon. Even when hits on the envelope are obtained, the gas escapes very slowly through the small punctures. Some years ago a spherical captive balloon was fired at with field shrapnel. An effective round was obtained, which gave 16 punctures in the envelope, caused by 8 bullets. The balloon took a quarter of an hour to sink to the ground from a height of 300 metres.

More recently, a larger captive balloon was fired at by German infantry with the new pointed bullet. It did not appear to suffer at all, but when it was hauled down it was found to have 76 punctures in it, which had practically closed up owing to the contraction of the fabric.

Perforating a balloon by a direct hit with an ordinary shell is almost impossible, on account of the difficulty of hitting it. The shell disappears when fired, and the gunner has no means of knowing where it has gone with reference to the balloon. The only means so far devised of hitting a balloon is to use a shell which leaves a visible trail behind it, such as the Krupp shell shown in the Plates. And if such a hit can be obtained, it is preferable to take advantage of it to burst the balloon or set it on fire.

Two kinds of smoke-trail shell have been devised; the Krupp incendiary shell, and the Semple tracer attachment. The latter is described in the chapter on Ammunition.

The Krupp incendiary shell is filled with smoke composition, which is ignited by a fuze on discharge and burns through holes in the shoulder of the shell. It can produce no effect whilst passing through the balloon, since there is no air to combine with the hydrogen; but as it passes out it sets fire to the escaping gas. This is the intention; but it is doubtful whether Messrs. Krupp or anyone else have succeeded in setting fire to a balloon in this way.

The Semple tracer (page 168) which can be attached to the base of any shell, serves the same purpose as the composition in the Krupp shell. But it would have to be made extra large—say ¼ the weight of the shell—to give a good smoke trail over a long range. Whether it would set fire to a balloon has yet to be determined.

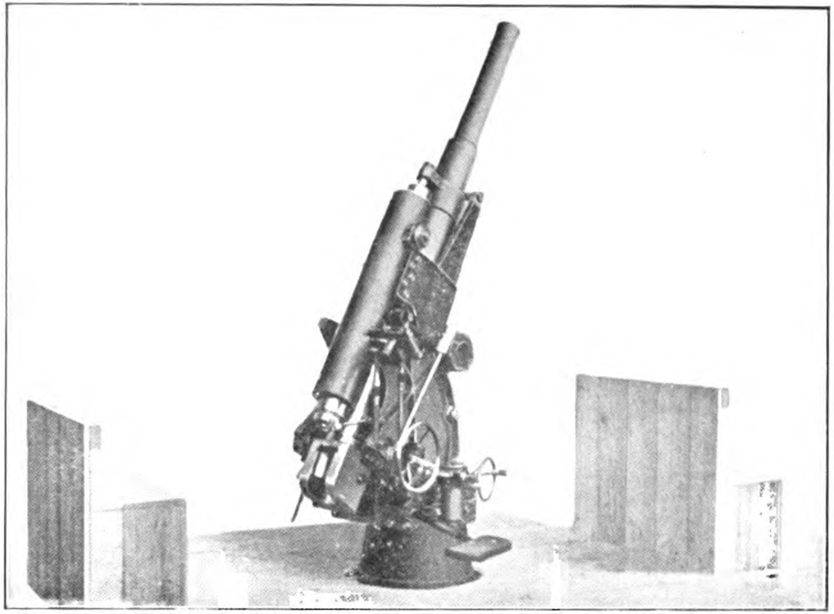
The Krupp high-explosive balloon shell is the same as the incendiary shell, with the addition of a high-explosive charge in the head and a sensitive fuze. There can be no doubt that the detonation of this shell upon the envelope of a balloon, of whatever type, would destroy it. The difficulty is to provide

Page 186.—The Krupp sensitive fuze for balloon guns has a projecting contact-pin, held in position by the friction due to two centrifugal levers, of which the inner ends press upon the pin while the outer ends tend to fly out. When the contact pin is pressed in it releases the striker.

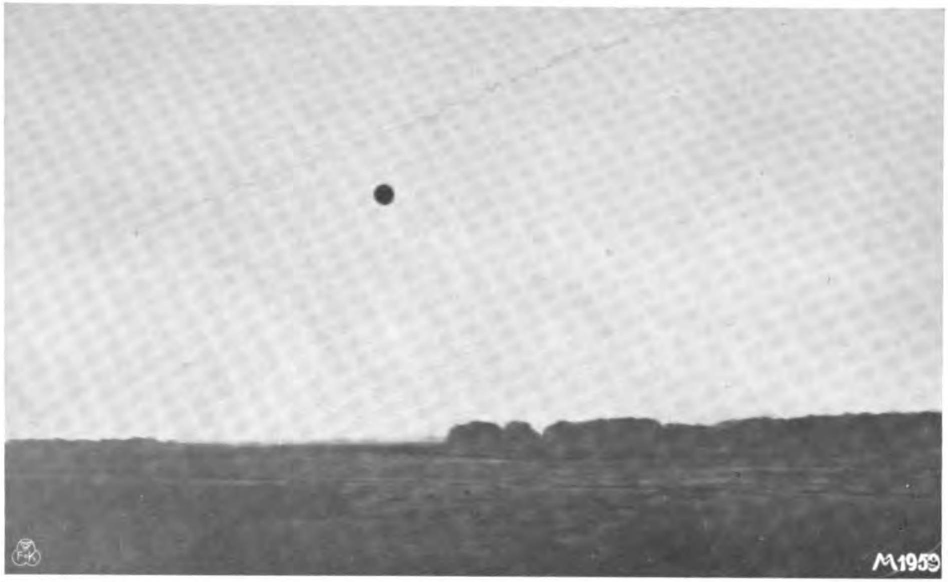
... It is however doubtful whether this would act quickly enough. The *trigger fuze* is actuated by a spring wound up before firing, and released on impact by a touch on a projecting trigger. The *electric fuze* contains a dry battery and electric detonator, which acts when contact is made by pressure on a projecting contact pin. It would seem by no means an easy matter to make a safe and reliable fuze of any one of these types. This is a difficulty which will have to be overcome, since the high-explosive shell is the only one which is of any use for attacking an aeroplane.

Aeroplanes are practically invulnerable to shrapnel bullets, since the planes might be riddled with bullets without doing much harm, while the chance of hitting the aviator or the framework is small. Neither would incendiary shell affect them; but the detonation of a high-explosive shell would probably rip the planes and smash the framework.

From the foregoing we may infer that the size of the shell is determined by the amount of smoke composition which it has to contain; and this depends on the range at which the shell has to be used.



KRUPP 12 pr. BALLOON GUN,
ON TRANSPORTABLE PLATFORM.



PRACTICE AT BALLOON WITH KRUPP SMOKE-TRAIL SHELL.

Now Count Zeppelin has laid down that a dirigible balloon will never rise higher than 5000 feet, unless on extreme emergency; and it seems at present unlikely that aeroplanes will reach this altitude. Hence the vertical range is very limited. The horizontal range depends on the distance at which there will be a fair prospect of hitting an air-ship. The Zeppelin IV, for instance, is 446 feet long by 43 feet high, and the 50% vertical rectangle of a modern field gun is about 40 feet high at 5000 yards, so that the dirigible would be easy to hit at that range if we could get a sitting shot. When moving at 40 miles an hour the Zeppelin would not be such an easy target; but we may take it for granted that fire would certainly be opened on an air-ship

Page 187.—In 1912, the Comte airship attained a height of 9900 feet with 6 persons, and the Zeppelin II, with 12 persons, rose to 5400 feet. The airman Legagneux ascended to a height of 18,635 feet in a monoplane, taking 40 minutes to do so.

It has been suggested that a delay-action fuze might be employed which, when firing at a distant balloon, would be set so as not to ignite the smoke composition till the shell had travelled some 2000 yards, thus saving composition and leaving more room for the high explosive. But, in view of the rapid rate of fire which will be required, this complication appears undesirable.

Messrs. Krupp, who are the pioneers in this subject, consider that a 12-lb. shell is the smallest size which it is advisable to use, while for balloon guns on permanent mountings they recommend a 40-lb. shell.

It will be difficult, even with a good one-man rangefinder, to determine the range of a rapidly-moving dirigible with any approach to accuracy, and hence a high-velocity gun, giving a flat trajectory, is required. It must be mounted so as to be capable of at least 75° of elevation, and must be capable of being rapidly traversed through a considerable arc. Practically, this combination of requirements renders it impossible to construct the balloon gun as a field gun of the ordinary type.

The solution at which Messrs. Krupp have arrived is illustrated by the annexed Plates.

The gun is a 12 pr., 35 calibres long, firing high-explosive smoke-trail shell with M.V. of 2050 fs. It is mounted on a pivot, and is capable of all-round traverse and of elevation up to 75°. The greatest height of the trajectory at 75° is 6000 metres. It is mounted on a travelling platform, either drawn by a motor or forming part of a motor wagon. In order to reduce the recoil-energy, the gun is mounted on the differential recoil system, with compressed air running-up gear, and no buffer. In order to render the breech easily accessible at all elevations, the cradle is on rear trunnions. The motor wagon is capable of 30 miles an hour on the level, and has an independent drive to each of its four wheels to enable it to travel off the road. But there is no idea of chasing an air-ship across country; the motor is provided because the gun and pivot alone weigh 22 cwt., and this, with the platform, ammunition, and detachment, constitutes a load too heavy for a team of horses. The total weight of the motor wagon with gun and ammunition but without detachment in 4½ tons.

Messrs. Krupp have also a horse-drawn 9 pr. equipment, intended for countries unsuitable to motor transport, but this cannot compare in efficiency with the 12 pr. The wheels of the gun are pivoted like the front wheels of a motor car, so that they can be turned at right angles to the trail for traversing. The muzzle velocity is 2035 fs.; the gun is 35 calibres long, and is capable of 70° elevation. It has a buffer and running-up springs, and is on rear trunnions. The weight in action is 18 cwt.

The annexed Plate shows a balloon struck by a high-explosive shell from the Krupp 12 pr. The explosion has destroyed the lower part of the envelope, and blown off the top portion, which is seen slowly sinking. The smoke trail left by the shell is plainly visible. The black cloud is due to the dispersion of the unexpended smoke composition by the detonation of the head of the shell.

Sights for Balloon Guns.

The ordinary sight for a balloon gun is a low-power telescope, magnifying about 3 diameters, with the eye-piece set at a right angle to the axis. There is however a complication involved. The principle of the rigidity of the trajectory does not hold good at high elevations, and the angle of elevation to a balloon distant 5000 yards and 5000 feet high will be less than to the balloon at the same range when 500 feet high, while if the balloon be vertically over the gun the angle of elevation will be *nil*. The relation between the angle of sight and the angle of elevation can be expressed in the form of a curve, and a cam can be cut to introduce the corresponding correction.

This cam can be applied in different ways. If the gun be mounted on the independent line of sight system, then the cam may be applied to the sight and actuated by the laying wheel, so that the angle which the telescope makes with the intermediate carriage is altered as the angle of sight is increased. This amounts to applying the correction to the angle of sight. The Krupp balloon guns are not mounted with the independent line of sight. The elevating wheel has two functions; in the first place, it elevates the gun and sight; in the second place, by means of a cam attachment, it shifts the index by which the sight (which is in the form of a drum) is set. This amounts to applying the correction to the angle of elevation. In either case the accuracy of the correction depends upon the platform being truly horizontal. But the total amount of the correction is small, and an error of a couple of degrees in the level of the platform makes no great difference to the result.

Correcting Gear.

As regards the construction of the corrector cam, it must be borne in mind that the amount of the correction depends upon the angle of sight, that is the angle which the axis of the sighting telescope makes with the horizontal plane, not upon the quadrant angle of the gun. If the correction be given by shifting the index of the range drum, the cam controlling the index must be fixed to the mounting and actuated by the movement of the sighting telescope with reference to the mounting; this movement may be due to setting the sight for elevation, or elevating the gun to bring the telescope on to the balloon,

BALLOON DESTROYED BY KRUPP HIGH-EXPLOSIVE SHELL BURSTING ON ENVELOPE.

or both. The practical effect will be that every time the sighting elevation is altered, or the gun is elevated or depressed, the index will shift. The elevating number will have to be "hunting his index"—that is, keeping the elevation ordered opposite to the shifting index—so long as the target is in motion. It is possible to use a fixed index and shifting scale, but this means a considerable increase of complication. In practice it is found quite easy to give elevation by the shifting index, since it does not move far enough or fast enough to give any trouble.

French Experiments.

The French Government carried out firing trials at balloons at Bourges in 1908. The only result arrived at was that field guns and field howitzers are altogether ineffective at a free balloon, but that with a well-arranged system of cross observation a captive balloon, at heights up to 500 metres, can be quickly disabled. Accordingly the construction of a high-angle gun for attacking dirigible balloons was ordered. No details have been published, but it is stated that the gun is generally similar to the Krupp 12 pr. equipment.

The Ehrhardt balloon gun.

Messrs. Ehrhardt have approached the problem from a different point of view from Krupp. They mount a comparatively small and light gun—a high-velocity 6 pr.— on a fast motor car, with the object of chasing the balloon and destroying it by rapid fire at short range. The feasibility of this idea is doubtful. The roads in the theatre of war would probably be too encumbered to admit of fast travelling, and the balloon, when chased or attacked, could escape by turning down wind. The Ehrhardt balloon gun fires a high-explosive shell with sensitive fuze. The fuze is locked by centrifugal bolts, connected to serrated wings which project outwards from the shoulders of the shell in flight; these are intended to tear the envelope of the balloon.

Messrs. Ehrhardt have also brought out a 9 pr. for attacking balloons. This is to fire the combined shrapnel and high-explosive shell described under Ammunition, and has a time and percussion fuze warranted to act on impact on the envelope of a balloon. The fuze also contains a column of smoke composition which burns during flight, leaving a visible trail.

More recently, the same firm have brought out a 14.3 pr. balloon gun. This is 35 calibres long, M.V. 2135 fs., and is capable of 75° elevation.

Danger to our own Troops.

It has been objected to balloon guns in general that our own troops will be endangered by the shells falling on their heads. This objection is, however, unsound; even if the balloon is attacked by a rival dirigible or aeroplane, it has to be destroyed by projectiles of some sort. And it matters little to the soldier below whether a shell which falls on his head from a height of 5000 feet weighs one pound or twelve. Moreover the Krupp 12 pr., for instance, ranges some 8 miles at 45° elevation, so that at any rate the troops in the vicinity of the gun would not suffer. Finally, since the object in view is to bring down some tons of balloon or some hundredweight of aeroplane from the sky, the incidental fall of a few 12 pr. shell would appear to be a minor matter.

Part III.

PRACTICAL GUNNERY.

CHAPTER XXII.

PRACTICAL GUNNERY.

The Choice of a Position.

An artillery "position" does not necessarily mean a defensible feature of the ground. It merely means the place where the guns come into action, and may be anything from a hollow road or a corn field to a commanding ridge.

It is most desirable that the guns should stand on firm and level ground, free from large stones. Unless the ground is firm the spade will not take hold properly, and the gun will tend to move sideways during firing. For howitzers, a sound platform is especially important.

If the ground slopes down to the front it is often impossible to get sufficient elevation at the first round, before the spade is embedded, especially when (as is frequently the case in hilly country) the target is above the gun.

If the gun be on a steep reverse slope, firing at a low angle of elevation, then the axis of the piece will make a large angle with the trail and the gun will jump instead of remaining steady on firing.

Large boulders in the ground prevent the spade from taking a fair bearing, and make the gun exceedingly difficult to traverse.

Whenever the ground is bad, it will be found to save time if the section commanders and layers are fallen out before coming into action, to select emplacements for their guns.

Since guns must have a good view of the battlefield, they are usually posted on high ground. The choice of position, for direct fire, will as a rule lie between the forward crest and the rear crest.

Fig. 77.

The forward crest position gives a better view, and the guns, being below the sky-line, are difficult for the enemy to locate, so long as the men keep still. There is a position on Salisbury Plain with a low irregular gorse-covert behind the guns, which are fully exposed to view in front of it. A battery in this position is most difficult to make out, provided that its fire discipline is good and that there is no unnecessary running about.

On the other hand, the forward position renders ammunition supply difficult. And with a quick-firing gun, which has a long trail with a large spade at the end of it, it is often impossible, on a forward slope, to get sufficient elevation for the first round without digging in the spade. When this happens it is sometimes advisable to fire off the ranging section guns with as much elevation as can be got, even if insufficient to reach the target. This will bury the spades and give another two or three degrees of elevation.

As a rule, the forward crest position makes it easier for the enemy to range, since *plus* rounds can be observed.

The rear crest position has the serious drawback that the guns must stand up above the sky-line, and also that the field of view is inferior to that obtained from the forward crest. The former disadvantage may be minimised by keeping the guns run back till required to open fire; the latter, by keeping look-out men with glasses in front of each flank.

Cover for Limbers and Wagons.

The slope of descent of a field shell at 3000 yards is about 1 in 6; that of the lower bullets of a shrapnel is about 1 in 5. Now a hill with a slope as steep as 1 in 5 from top to bottom is rarely to be met with. It follows that it is practically impossible to obtain cover for the limbers and wagons by posting them at the foot of the hill close behind the guns.

Since many of the shell fired at the guns will burst quite 200 yards over, and since the shrapnel bullets are effective 300 yards beyond the point of burst, it follows that the line of limbers and teams must be *at least* 500 yards in rear of the guns, or still further if the range is a short one. It is sufficiently obvious that it is not desirable to place the limbers and teams directly behind the battery if this can be avoided.

FIELD ENTRENCHMENTS.

This question will only be touched upon in so far as gunnery questions are involved.

In entrenching a gun, the first thing to see to is that the gun can be turned upon any target which it may be required to fire upon. If an embrasure is used, the space inside the gun-pit or entrenchment must therefore be large enough to allow full traverse for the gun.

Protection for the detachment is the next consideration. This is best provided by digging deep trenches on either side of the gun, in which the men, when not actually serving the gun, can sit with their backs to the parapet, their heads being at least a foot below the crest, which must be thick and solid. It must be remembered that the angle of descent of shrapnel bullets, at medium ranges, is about 1 in 5, so that protection is only obtainable close under the parapet, unless overhead cover can be constructed.

A liberal supply of ammunition must be provided for.

The best position for the gun-entrenchments is usually the forward crest; on no account must they be on the sky-line.

Shelters for the battery commander and section commanders must be provided.

It is hardly necessary to say that gun-pits should not be so constructed as to afford targets for the enemy. When possible, they should be combined with natural features of the ground.

With ten gunners digging, and three drivers cutting sods, it takes from three to four hours to provide good cover for a gun, or double the time to construct overhead cover, provided that timber is handy.

If dummy entrenchments are used, these should be at such a distance from the real ones that the latter will be well outside the total rectangle of shots fired at the dummies. Under service conditions, at medium ranges, the total rectangle may be taken at 500 yards × 100 yards.

Concealment of Flash.

Practical experience shews that the broad white flash from the muzzle of a field gun firing smokeless powder is visible when the gun is behind cover, unless the muzzle is at least ten feet below the covering crest. This means that the gun must be placed at a point of the reverse slope which is at least 13 feet below the crest, otherwise the enemy will be able to locate it when it opens fire.

A field howitzer firing full charge will probably require 20 feet of cover above the muzzle.

Position for Indirect Fire.

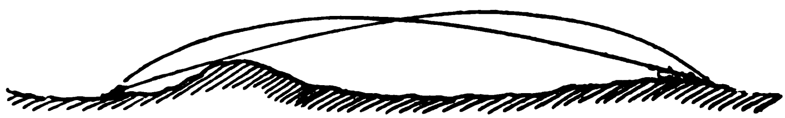


FIG. 78.

For a field gun, the angle of descent of a shell is about one-third greater than the angle of elevation. If a battery be firing at 3600 yards, which corresponds to about 6 degrees of elevation, then the angle of descent of its shell will be 8 degrees. If, therefore, two batteries of similar guns are firing at each other, both being under cover so that their shell barely clear the covering crests, each will be able to hit the other. In other words, when engaging a hostile battery it is impossible to obtain natural cover from its fire. The advantage of the covered position is solely due to concealment from the enemy's view. It follows, therefore, that the cover afforded by trees, houses, hedges, etc., is just as good as that afforded by a rise of ground. A practical exception to this rule is that the cover must not be of such a nature as to act as a penetrable screen to burst the enemy's shrapnel within effective distance of the battery.

Forward and Retired Covered Positions.

Suppose the reverse slope of a hill to average 4°, or 1 in 15, and

FIG. 79.

the angle of elevation, for 2500 yards, to be 3° 40′. Then to clear the crest the gun must either be posted back from the foot of the hill, or upon the more gentle slope near the top of the hill. The latter is in many ways the better position; it admits of greater quickness in taking up the position and in changing target, and easier observation; it also renders it possible to run the gun up to the "rear crest" position if required to change to direct fire. But it must be borne in mind that unless the gun is 10 feet below the crest the flash will be visible as soon as the battery opens fire, enabling the enemy to locate each gun. The forward covered position is then dangerous if the enemy's artillery is in superior force.

The rear covered position requires the crest of the hill in front of it to be kept clear for a distance equal to the front of the battery, plus a distance on either side equal to that of the battery from the crest. This is necessary in order not to infringe on the "danger angle" of 45° from the muzzles of the flank guns.

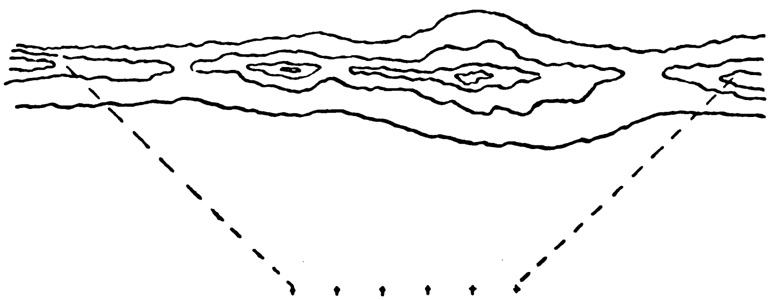


FIG. 80.

That is, if the battery is 100 yards in rear of the crest, it will require the crest to be kept clear of other troops and other guns for 300 yards; if 200 yards in rear, the battery will require 500 yards of crest to itself. Further, if the battery commander observes from the crest he will need to be, in the latter case, 200 yards to the flank.

Command of the Foreground.

The flat trajectory of a modern field gun imposes certain limitations on it, which must be borne in mind when selecting a covered position. Thus the angle of elevation of the 18 pr. is only 3° 5′ for 2000 yards and 5° 21′ for 3000 yards. Therefore if the covered position be such as to require 3 degrees of elevation to clear the crest, the whole of the foreground within 2000 yards of the guns will be dead ground. Therefore, on the defensive, guns in covered positions will have to be content with the minimum of cover necessary to screen them from view. The bottom of a deep valley will be useless as a covered

Page 196.—Command of the Foreground. If the shrapnel from a battery in the concealed position be fired so as to clear the covering crest, and to burst just beyond it, the droop of the bullet-cone will cause the bullets to sweep the exterior slope

position, and the guns will have to be placed either well back from the covering crest or close up to it. In the attack, the knowledge of this limitation may be of use in locating concealed guns.

The Observing Position.

This is even more important than that of the guns. On the one hand, it must command a good view of the field of fire ; on the other hand, it should not be unduly conspicuous, since well-marked features will form targets for the enemy. It is desirable that the position should be near the guns, but this is of less importance than a good view. It is not necessary that the guns should be visible from the O.P., provided that a director set up near them can be seen.

CHAPTER XXIII.

THE OCCUPATION OF A POSITION.

Intervals.

A most important matter, from a gunnery point of view, is the necessity of maintaining the full interval of 20 yards between the guns.

It will be readily understood that if this interval be reduced an enemy's shrapnel may take effect upon two gun detachments instead of one, doubling the number of casualties. The mathematical calculations bearing on this point depend upon the Theory of Probabilities, and must be studied in more advanced works than the present one. But it may be pointed out that the 20-yards interval has not been accepted without good reason by all civilised nations. The practical gunner may safely take it for granted that if he halves his gun intervals he will double the number of his casualties, and so in like proportion.

On the other hand, there is no direct gain from the use of unduly wide intervals. It requires no mathematics to show that if the interval be greater than the ordinary spread of shrapnel bullets—say 30 yards—one shrapnel cannot possibly hit two guns. Guns 50 yards apart are therefore no safer than if 30 yards apart. Nor is there much to be hoped for from shrapnel passing clear between two guns without hitting either. For, if widely dispersed, each gun will form a separate aiming-point for the enemy, and his gunnery must be very poor if he cannot get his line within ten yards.

METHOD OF OCCUPATION.

The tactical details of the occupation of a position are beyond the scope of this book. From a gunnery point of view there are four types of position. In the first, or direct position, the layers can see and lay on the target. In the second, or semi-covered position, the guns are posted just behind the crest, so that the layers, standing erect, can see to lay for line while giving elevation by clinometer. This is the favourite French position. In the third or advanced covered position the guns are near the crest, so that an officer standing behind the gun on a limber, or on the observation ladder, can see the target and direct an aiming post to be placed in line with it.

In the fourth, or fully covered position, the guns are so far below the crest that the target cannot be seen from the neighbourhood of the guns.

Neither the semi-covered nor the advanced covered position gives concealment from the enemy when once the guns have opened fire. For the flash of the gun is visible over the covering crest unless the muzzle is at least 10 feet vertically below it for field guns, or probably 20 feet for howitzers.

Except in the case of howitzers, which may be able to get close behind a steep covering mass, none of the four positions affords cover from the enemy's gun-fire. For, as explained above on page 195), if the shell from the battery can clear the crest, the enemy's shell can also do so. Covered positions would in fact be more correctly described as concealed positions. Theoretically, therefore, the best covered position is the one best adapted to keep the enemy ignorant of the position of the battery.

This condition, as will be seen, is fulfilled only by the *retired* or *fully-covered* position. It may however be necessary on tactical grounds to use the semi-covered or the advanced covered position. These have no advantage on the score of quickness in opening fire, since a battery equipped with dial sights can come into action behind a hill and get its line in much less time than it would take to manhandle the guns into position on the slope near the crest. But when it is anticipated that it will be necessary to run the guns up to support or to repel an attack by direct fire, then they should usually be posted near the crest to avoid the necessity of bringing up the teams under fire.

The method of directing the fire of guns from a covered position will be dealt with in Chapter XXV.

Direct Occupation of a Position.

The ordinary methods of occupying a position are fully described in F.A. Training, and involve no special points of gunnery. There is, however, one method which is occasionally useful and merits consideration.

Suppose that a Q.F. brigade has to engage another Q.F. brigade already in position, and that on tactical grounds it is not desired to use indirect fire. Then the following method may be applied—

Run up a single gun by hand on to the position, or, preferably, to another point at the same distance from the enemy. It will usually be possible to find cover for this gun so that it will take the enemy some time to locate it. Range and find fuze with this single gun, and let the rest of the brigade load, set sights, and prepare fuzes. Then let the whole brigade come into action direct and open rapid fire at once.*

Allowing one minute for laying and pointing out target, in the second minute the brigade should be able to fire from 200 to 250 rounds of time shrapnel. The suddenness and vigour of the attack, if properly carried out, should at least neutralise the advantage enjoyed by the enemy of being already in position.

SELECTION AND DISTRIBUTION OF TARGET.

In selecting the target, tactical considerations are paramount. The increased rate of fire obtainable from modern guns must, however, inevitably lead to a departure from older methods. Thus if several targets present themselves simultaneously to a battery—such as three different bodies of infantry—the maximum effect will usually

* **NOTE.—I am indebted for this suggestion to General Lindsay, D.S.O., R.F.A.**

be obtained by assigning one to each section. A well-trained section, after completing its ranging, should be able to fire 100 rounds of time shrapnel in five minutes. Supposing that at a favourable target, under service conditions, only one hit per shell is obtained, this still represents a considerable—probably a decisive—result. If the whole battery were turned on to one target, the other two bodies of infantry would escape for ten minutes at least, and possibly get off scot free. Opportunities of engaging favourable artillery targets are fleeting, and when such occur the Battery Commander should not hesitate to utilize the full power of his guns to take advantage of them.

Distribution of Target.

In ordinary cases the simplest and best method is for each battery and each section to engage the portion of the target opposite to it. The rule is, however, subject to modification.

Thus, suppose a F.A. brigade engaging a hostile F.A. brigade. The C.O. finds that his fire, though effective, is not sufficient to silence the enemy. His best course is to concentrate the fire of his whole brigade, less two sections, upon each of the enemy's batteries in turn. The two remaining sections, by sweeping and increasing their rate of fire, can maintain the fire upon the two remaining hostile batteries.

There are two reasons why this concentrated fire is especially effective. The first is the moral effect, which is of the highest importance, but is not a matter of exact science. The second is, that while it is often possible for a man to obtain cover from bullets coming only from one direction, this is less easy when the bullets come in from three directions at once.

Cross Fire.

At medium ranges, when observation is easy, cross fire may sometimes be employed. Thus if a F.A. brigade is engaging a line of entrenchments a quarter of a mile long at 3000 yards range, it may be advisable to order the Eastern battery to fire on the Western end of the enemy's line, and vice versâ. This is because a trench or a parapet affordls less protection from oblique than from frontal fire, and none from enfilade fire. Suppose the angle of descent of shrapnel bullets 1 in 6, then a man kneeling 3 ft. 6 in. high would be safe against frontal fire if he knelt 1 yard in rear of a 4 foot parapet. But a bullet coming over the parapet at an angle of 45° from a flank would take the man $6(\sqrt{2}-1)$ or 3.5 inches below the top of his head.

CHAPTER XXIV.

SHRAPNEL FIRE.

The construction of a shrapnel shell has already been described. We know that it consists of a steel envelope containing bullets, which are blown out forwards by a bursting charge, or rather driving charge, in the base of the shell when this charge is exploded by the action of the time fuze.

We will now consider what happens to the bullets when thus blown out of the envelope.

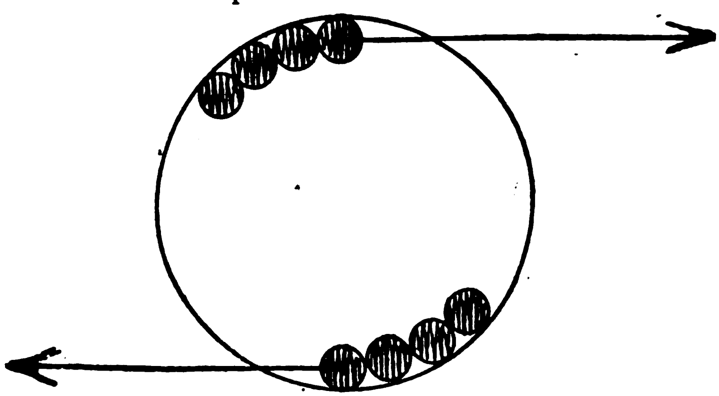


FIG. 81.

The Angle of Opening.

Take first the outer ring of bullets, namely those lying against the inner wall of the envelope. Before the shell bursts, each of these is travelling round and round the centre of the shell at a velocity determined by the twist of the rifling and the M.V. of the shell. This velocity may be calculated as follows—

Take the shrapnel of the 15 pr. B.L. gun.

Here the shell makes 1 turn in 28 calibres, or 28×3 inches, or $\frac{28 \times 3}{12}$ feet. The M.V. of the shell being 1581 feet per second, it travels 1 foot in $\frac{1}{1581}$ seconds, or $\frac{28 \times 3}{12}$ feet in $\frac{28 \times 3}{12 \times 1581}$ seconds, or $\frac{1}{223}$ second; that is, the shell makes 223 turns per second.

It was formerly supposed that the velocity of rotation of the shell remained much the same to the end of its flight. Recent experiments, mentioned in the chapter on Rifling, have however caused this view to be modified, and it is now considered that the 15 pr. shell loses 20% of its velocity of rotation at 3000 yards, and 30% at 5000 yards. Shell which are steadier in flight and of larger calibre, such as the 18 pr., lose their velocity of rotation at about half this rate.

For the 15 pr. B.L. at 3000 yards, we may therefore take the velocity of rotation of the shell at the point of burst at 179 turns per second.

Next use the diagram of the shrapnel shell in the official handbook, and measure the distance of the centre of one of the outer bullets from the centre of the shell; we find that the distance is a trifle under one inch, and that the circumference of the circle passing through the centres of the outer bullets is 6 inches exactly.

Therefore, as the shell rotates, each bullet travels a distance of 6 inches 179 times per second, or say 90 feet per second.

If now the bullets be suddenly released from the containing envelope, it is clear that in the figure (in which the shell is looked at from behind) the top bullet will fly in the direction of the arrow with a velocity of 90 feet per second, and similarly for the rest of the bullets in the outer ring. This velocity is called the *tangential* or *centrifugal* velocity.

But the bullets, and the envelope containing them, are also travelling forwards at a rate varying with the range.

For 3000 yards, for instance, we find from the range table that the remaining velocity is 819 feet per second.

To this velocity we may add the forward velocity due to the bursting charge of 1¼ oz. of R.F.G. (rifle fine grained powder) which blows the bullets forward out of the envelope.

This velocity is found by experiment to average about 100 feet per second for this gun.

We may take it, then, that at the instant of burst each bullet is travelling forwards at the rate of 919 feet per second. At the end of one second after burst the top bullet in the drawing will have flown (neglecting for the present the resistance of the air) 919 feet forward and 90 feet to the right; the bottom bullet will have flown 919 feet forward and 90 feet to the left.

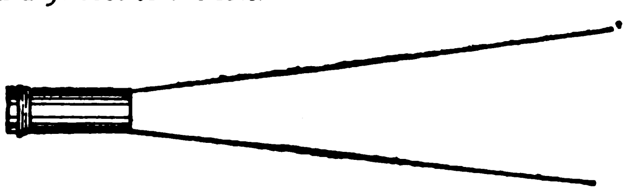


FIG. 81a.

The angle between the directions taken by the outermost bullets is called the *angle of opening*. In the above instance it is 11° 40′, or about 1 in 5.

Distribution of Bullets.

So far we have not taken into account the inner bullets of the shrapnel shell. It is evident, however, that the centrifugal velocity of the inner bullets must be less than that of the outer ones, while the forward velocity is the same. The inner bullets will therefore diverge at a less angle than the outer ones, and will all fall within the cone formed by the outer bullets. The exact distribution of the bullets is

governed to a great extent by the details of the interior arrangement of the shell, such as the shape of the diaphragm ; and it is the object of the designer of ammunition, like that of the gun-maker, to get as good a " pattern " as possible.

Air Resistance.

In calculating the angle of opening it has been assumed that the velocity of the bullets remains equal to the remaining velocity of the shell (plus that due to the forward impulse of the burster) up to the end of the first second.

But although this is not the case, the velocity being reduced by the resistance of the air, this reduction does not affect the angle of opening. For each bullet assumes its new direction as soon as it issues from the shell, and the resistance of the air is opposite to this new direction, and does not tend to make the bullet deviate from the straight line. The effect of the air-resistance is therefore to shorten the cone without affecting its angle. At the end of the first second the bullet will therefore not have travelled 919 feet forward and 90 feet sideways, but 640 feet forward and 63 feet sideways.

Effect of Range upon Angle of Opening.

With the 15 pr. shell, the loss in rotational velocity between 3000 yards and 5000 yards is in nearly the same proportion as the loss of forward velocity, so that, allowing for the constant addition of bullet velocity due to the burster, the angle of opening is but little affected. With the 18 pr., and with other Q.F. shell which are equally steady in flight, the velocity of rotation falls off more slowly in proportion to the forward velocity, so that for the 18 pr. the theoretical minimum angle of opening (taking the increased velocity due to the burster at 133 fs.) increases from $8^\circ\ 2'$ at the muzzle to $11^\circ\ 48'$ at 3000 yards and $12^\circ\ 34'$ at 5000 yards.

Similarly, the angles of opening given in the official range table for the Dutch 13.2 pr. Krupp gun show the following increase as the range lengthens:

Range, metres:	1000	2000	3000	4000	5000
Angle of opening	$7^\circ\ 30'$	$9^\circ\ 30'$	$11^\circ\ 30'$	$12^\circ\ 30'$	$13^\circ\ 30'$

It is not stated whether these are calculated or experimental results.

With a howitzer fired at 45° elevation, there is little rotational velocity left at the end of the shell's flight, and the angle of opening is principally that due to the gases from the burster getting among the bullets.

Minimum Angle of Opening.

The angle of $11^\circ\ 40'$ above determined is the minimum angle which the bullets of this shrapnel can assume under the conditions stated. But this angle is invariably exceeded. This is due to the bullets colliding among themselves and rebounding outwards,* and to the

* NOTE.—In Messrs. Krupp's experiments with armour-piercing steel shrapnel bullets it was found that, owing to the elastic rebound of the bullets, the angle of opening was from 2 to 3 degrees greater than that obtained with mixed metal bullets.

lateral expansion of the burning gases which issue with the bullets from the shell. This latter action is especially marked if the central tube is burst or torn from the diaphragm on explosion, allowing the gases from the charge to penetrate into the centre of the mass of bullets. The smoke-producing charge, consisting usually of coarse black powder introduced among the bullets, also helps to increase the dispersion.

The effect of these various disturbing factors is not easy to determine. But in practice we may take it that they increase the angle of opening by about 30 per cent.

This would make the angle of opening of the 15 pr. B.L. shrapnel at 3000 yards about 15 degrees 30 minutes.

The Bullet-Cage.

For reasons which will presently be apparent, this angle was considered too large by the authorities, and a cage of perforated tinplate (in the earlier marks, of wire) was added to keep the bullets together. The effect of the cage is difficult to estimate theoretically. But in practice it may be taken as reducing the angle of opening of 15 pr. B.L. shrapnel at 3000 yards to 14°, or 1 in 4.

WEIGHT OF BULLETS.

Having determined the angle of the bullet-cone, we have next to consider the flight of the individual bullets. This depends upon their initial direction, their weight, and their cross section.

Disabling Energy.

For any given remaining velocity, the minimum weight of a bullet is that which is sufficient to produce a disabling wound upon man or horse. It is desirable to have the bullets as small as possible, in order that we may pack the greatest possible number into a shell. We must therefore so adjust the weight of the bullet that at the longest range at which the gun is to be used, and at a distance from the point of burst sufficient to cover inevitable errors in ranging, the weight and velocity of the bullet, taken together, will suffice to render it an effective projectile.

Stopping Power.

The most convenient way to estimate the "stopping power" of a bullet is by means of its energy, or the power stored up in it, which is equal to the weight of the bullet multiplied by the square of its velocity. Now the energy of a bullet is, from the point of view of the man hit, by no means an infallible measure of its disabling effect. Thus a large bullet travelling comparatively slowly would probably do more damage to a man than a small one flying at a high velocity. Still, as between bullets which do not differ much in weight, the striking energy may be taken as a rough basis of comparison.

German and English Estimates.

The minimum disabling striking energy is a matter of more or less empirical estimate. Experiments carried out in Germany have led to its being fixed by German writers at 58lbs. In England we prefer

a slightly higher energy, possibly in consequence of the greater vitality of the uncivilized enemies against whom we are accustomed to use our shrapnel. Taking into consideration the fact that the average conscript is only too glad of an excuse to be carried to the rear by two comrades, we shall probably be safe in fixing the minimum disabling energy of a shrapnel bullet at 60 foot-pounds.

Effective Distance.

Next we consider the distance from the point of burst at which the bullet is required to be effective. We can hardly expect a bullet to be effective at a quarter of a mile from the point of burst at extreme ranges of 6000 yards or so. Even if such a bullet were introduced, its energy would be wasted, since the angle of descent at such a range is so sharp that the central bullets of the cone strike the ground at a distance less than double the height of burst, while even the upper bullets of the cone do not ordinarily carry more than 100 yards.

Suppose, then, that we take 3500 yards as our ordinary artillery distance—and we should only rarely get a longer range in an enclosed country—and 300 yards as a distance from point of burst sufficient to cover ranging errors and to sweep a fair depth of ground behind the target.

At this range the remaining velocity of a modern Q.F. shrapnel is about 900 fs. To this we may add 100 fs. for the forward impulse given by the bursting charge, so that the bullets start with a velocity of 1000 fs. Theoretically the forward impulse should be greater, and so it is in the case of the rear bullets, which get the full force of the charge. The front bullets, however, escape centrifugally beyond the edges of the shrapnel body before the full force of the burster is developed, so that in practice we cannot reckon on an average impulse of more than 100 fs.

Starting with a velocity of 1000 fs., we have then to determine the minimum weight of the bullets so as to have an energy of 60 foot-pounds remaining at 300 yards.

Ballistic Coefficient of Bullets.

Here the problem is complicated by the relative weight and size of the bullets, which constitute their *Ballistic Coefficient.* It is plainly desirable to have the bullets as dense as possible, in order that their diameter may be small and that they may meet with little resistance from the air. Pure lead is the heaviest metal commercially available, but this is so soft that the bullets become flattened and distorted by the shock of discharge, spoiling their shape for flight. The lead has therefore to be alloyed with antimony to harden it, in proportions varying from 10 to 20 per cent. of antimony. The former composition, which is rather soft, has a specific gravity of 10, the latter of 9—we may take 9.5 as a fair medium.

Minimum Weight.

The direct calculation of the minimum weight from these premises is not a simple one. The easiest way is to take bullets of different weights and calculate their performance from the Gunnery Tables until we get one which satisfies the conditions.

With a starting velocity of 1000 fs. we find from the Tables that the velocity and energy of the different bullets, after flying 300 yards, are as follows:*

Weight of bullet.	Remaining Velocity.	Striking Energy.
35 to the pound	395 fs.	69.2 foot-pounds
38 „ „	388 „	61.51 „
42 „ „	378 „	52.83 „
45 „ „	370 „	47.24 „

If, then, we accept the assumption that at 3500 yards the bullet should have a striking energy of 60 foot-pounds 300 yards from the point of burst, it appears from the above table that the correct weight for the bullets is about 39 to the pound. But this is a point on which great diversity of views prevails. It is noticeable that the nations armed with low-velocity 14.3 pr. guns, with M.V. of only 500 m/sec. (1640 fs.), which gives a sharp angle of descent, have mostly adopted the light bullet of 45 to the pound. The French, with their flat-trajectory gun, use the heavy bullet of 38 to the pound. The Germans endeavour to compensate for the deficient range of their bullets by firing at several elevations; thus a German battery commander, having found the range to a firing line at 3000 metres, continues to fire at 2950, 3000, 3050, 3000, 2950 and so on, firing one round of battery fire at each elevation.

The Japanese, after their experience in the Manchurian War, increased the weight of their bullets from 42 to 36.5 to the pound. The Americans have done the same. But the boldest alteration is that made by the Swiss artillery.

The Swiss 1903 Q.F. equipment has a M.V. of 1590 fs. with a 14 lb. shell, giving only moderate remaining velocities, and sharp angles of descent, at medium ranges. The original shrapnel issued with the gun contained 300 bullets of 43 to the pound. These have now been replaced by a pattern containing only 215 bullets of 36.5 to the pound, with a driving charge of no less than 3½ oz. of powder. The Swiss artillerists evidently lean rather towards French than towards German methods, and their object seems to be to obtain a bullet-swept area not far short of that given by the heavier and more powerful French Q.F. gun. Provided that their shrapnel with 3½ oz. driving charge gives a good pattern, the sacrifice of 85 bullets out of 300 is probably warranted by the greatly increased area of beaten ground.

In these days of formations extended not only in breadth but in depth, a definite standing target, on which precise ranging is possible, will probably be the exception. Moreover the inconspicuous uniforms now adopted will increase the difficulty of distinguishing the enemy's troops, so that it will often happen that the only target is an area of ground in front of our own infantry, where nothing but rifle-flashes can be made out. In the writer's opinion it is therefore undesirable to reduce the weight of the bullet below the limit of 39 to the pound, which, at 3500 yards, gives a bullet-swept area extending to 300 yards from the point of burst. And the remaining velocity of the bullets should be increased by the use of a driving charge as large as it is possible to put into the shell without breaking it up.

*This refers to smooth machine-made bullets. Cast bullets offer a slightly greater resistance to the air. See page 21.

Special Bullets.

In spite of the above practical considerations, designers of ammunition are strongly tempted to increase the number of bullets in the shrapnel even at the expense of their individual efficiency. With a view to reconciling the antagonistic condition of the problem, attempts are constantly being made to increase the density of the bullets, so as to produce a small bullet, heavy for its size, which will keep up its velocity and so be effective at the same distance as a larger one of lighter metal. Tungsten or Wolfram has been frequently proposed for this purpose—it has a specific gravity 64 per cent. greater than lead. It has not, however, been produced as a homogeneous metal, and would have to be used in the shape of a powder enclosed in steel capsules. A better metal is steel alloyed with 16% of tungsten, which is nearly as heavy as lead. But the supply at present available is so small as to render its extensive employment practically impossible. An alloy of lead and mercury is heavier than pure lead, but is softer than the ordinary antimony alloy. The only practical way of increasing the density of bullets at present known is to form them by compression in a machine from a rod of metal, in the same way that rifle bullets are made. This gives an increase of density of some 3 per cent. over the cast bullets, and a smoother surface.

The Wille shooting shrapnel, designed to increase the range from the point of burst by the use of rifled bullets, has been described in Chapter XVIII. But this is still in the experimental stage.

Pressing-in Bullets.

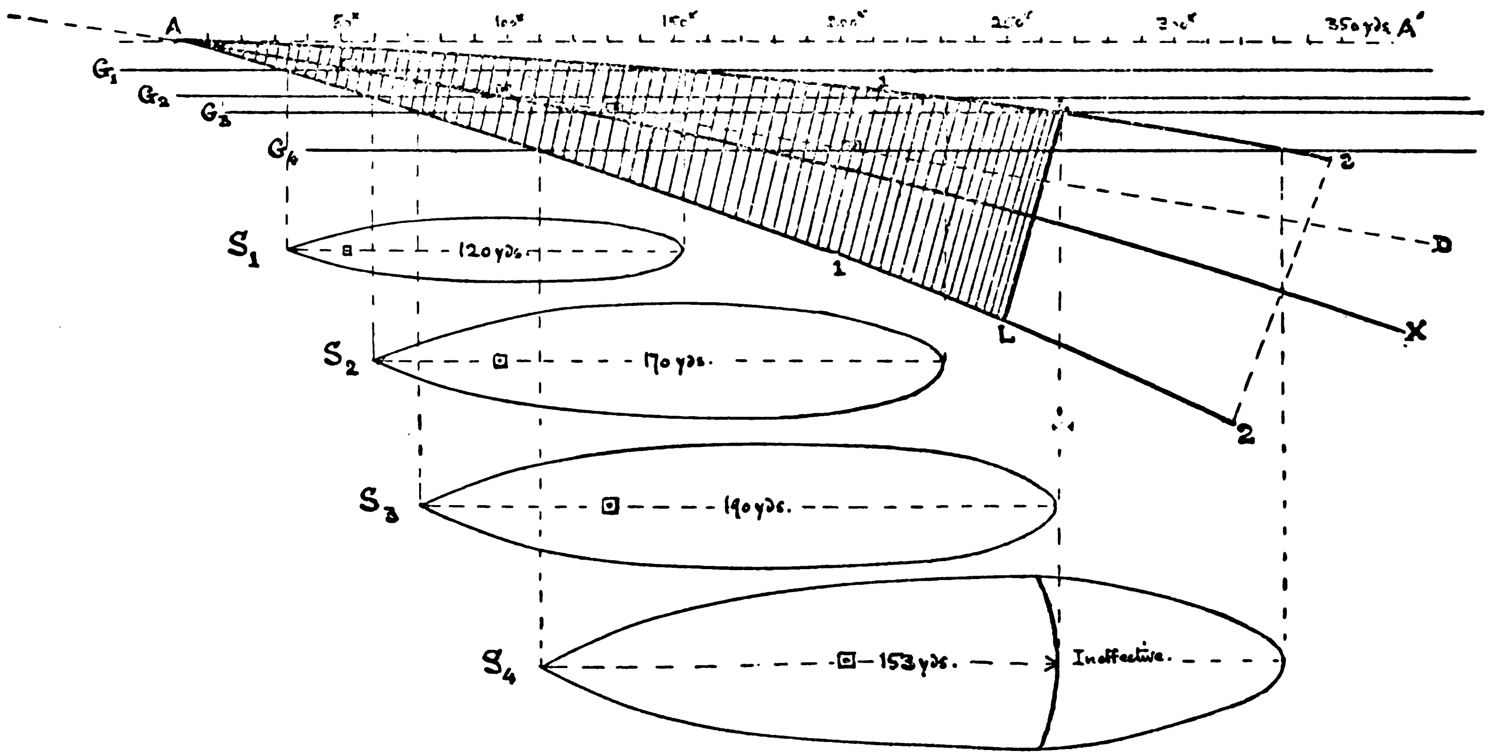
One way of getting more bullets into a shell, without reducing their size, is to press them together before introducing the resin, sulphur, or trinitrotoluol which fills up the interstices. The pressure is repeated three times during the filling of the shell, a dead-weight pressure of 10 tons being employed. This has the effect of pressing facets on the bullets where they touch, and so possibly slightly increases the resistance which they offer to the air in flight. On the whole, however, the balance of efficiency would seem to be in favour of the pressing system.

THE BULLET-CONE.

We have now determined the elements of the bullet-cone, namely the angle of opening and the weight of the bullets constituting it, while the range table gives us the initial direction of the axis of the cone. Remembering that a bullet under the influence of gravity falls 16.1 feet in the first second and 64.4 to the end of the next, we can now draw the profile of the cone.

Diagram A shows the bullet-cone of the 15 pr. B.L., while Diagram B, obtained by a similar calculation, represents that of the French shrapnel, burst at the same range of 3000 yards at the "hauteur type" or $\frac{3}{1000}$ of the range.*

*The data for the French gun are: Rifling 1 turn in 25 calibres, R.V. 1075 fs., and angle of descent 1 in 10. The practical angle of opening is 16 degrees; the bullets weigh 38 to the pound.



EXPLANATION OF FIGURE. **DIAGRAM A.**—Fig. 82.

The upper figure represents the cone of bullets of the 15 pr. B.L. shrapnel at a range of 3000 yards, seen from the side of the range.

AA′ is a horizontal line. A 1-1 is the cone up to the end of first second. A 2-2 the cone up to the end of the next second. LL is the limit of effective velocity, beyond which the bullets are harmless.

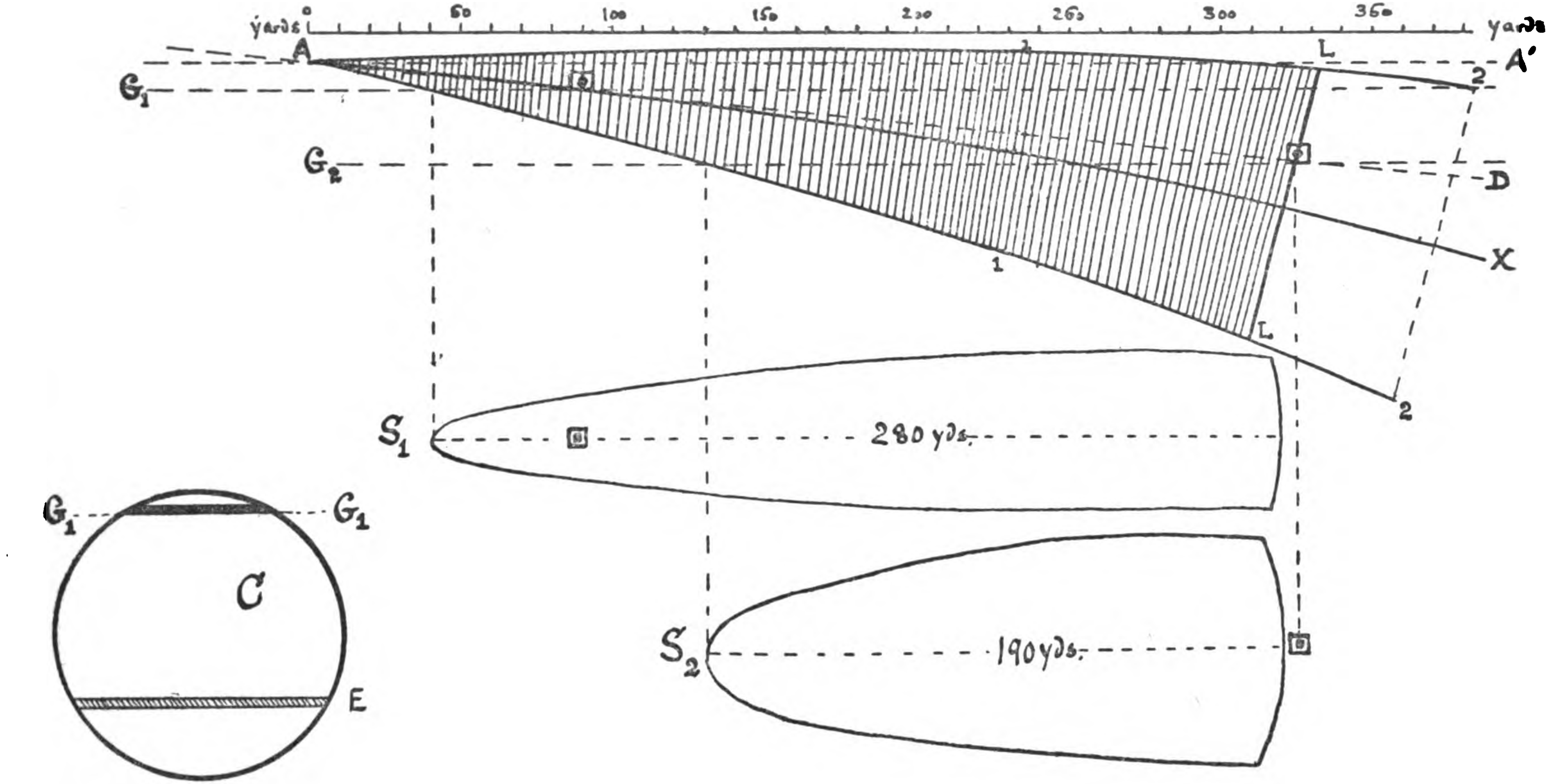
AX is the path of the central bullet of the cone.

AD is the prolongation of the trajectory of the shell before bursting, descending at an angle of 1 in $6\frac{1}{4}$.

G_1 is the ground surface drawn $\frac{3}{1000}$ or 27 feet below A, the point of burst; G_2 is the ground surface drawn 50 feet below A; G_3 is 65 feet below A, at the limit at which all bullets are still effective; G_4 is 100 feet below A.

S_1 S_2 S_3 S_4 represent in plan the beaten ground corresponding to each of the above heights of burst; that is, the section of the cone by the surface of the ground.

15 Pr. B.L. Shrapnel.



EXPLANATION OF FIGURE. **DIAGRAM B.**—Fig. 83.

The upper figure represents the cone of bullets of the French Q.F. field shrapnel at a range of 3000 yards, seen from the side of the range.

AA′ is a horizontal line. A 1-1 is the cone up to the end of the first second, A 2-2 is the cone up to the end of the next second. LL is the limit of effective velocity, beyond which the bullets are harmless.

AX is the path of the central bullet of the cone.

AD is the prolongation of the path of the shell before bursting, descending at an angle of 1 in 10.

G_1 is the ground surface drawn $\frac{3}{1000}$ or 27 feet below A; G_2 is 100 below A.

S_1 S_2 represent in plan the beaten ground corresponding to each of the above heights of burst; that is, the section of the cone by the surface of the ground.

FRENCH SHRAPNEL.

On comparing the diagram for the French shrapnel with that for the old 15 pr., we note several points of importance.

Length of the Cone.

Owing to the high remaining velocity and to the comparatively heavy bullet of 38 to the pound, the bullets at this range carry up to 330 yards or 300 metres nearly before losing their effective velocity. This is of great importance in connection with the French system of searching "registered" areas with time shrapnel.

Angle of Descent.

The high velocity gives a very flat trajectory with an angle of descent at 3000 yards of only 1 in 10. The effect of this small angle of descent is to keep the upper bullets of the cone off the ground till they have exhausted their effective velocity, thus giving a larger area swept by effective bullets, utilising the energy of the bullets to the best advantage instead of dropping them into the ground while still travelling fast enough to be effective.

Angle of Opening.

It will be observed that the bullets at the extreme top of the cone are ineffective at this range, as they do not descend to within 6 feet of the ground till they have lost their effective velocity. To obtain the maximum number of useful bullets the semi-angle of opening should not greatly exceed the angle of descent.

Distribution of Bullets.

Provided that the trajectory passes through the foot of the target, then the axis of the cone must fall short of the target, and more than half of the bullets will pitch in the small portion of the ellipse in front of the target. Over the rest of the beaten ground the proportion of bullets per square yard decreases with the distance from the target, till at 330 yards the only effective bullets are those in the small segment af the circular section of the bullet-cone cut off by the ground-line, as in Fig. 83, E. Even from these must be deducted the number which do not fall within 6 feet of the ground before losing their effective velocity. From this we learn that it is not sufficient to trust to the depth of the bullet-cone to sweep the ground thoroughly. Even when the range is correctly found at least half of the bullets must be short and therefore ineffective. For shrapnel bullets do not ricochet to any useful purpose; owing to their spherical shape they rise sharply after graze, and when they come down they are travelling so slowly as to be harmless. And supposing that the range is not correctly found, but is short of the target, then the number of bullets striking in the portion of the ellipse at and beyond the target will be only a small fraction of the whole.

Raising the Trajectory.

Supposing that the trajectory be raised by increasing the elevation without altering the fuze, then the distribution in depth will be improved, a larger number of bullets pitching over the target. This proceeding is occasionally permissible, as when the target consists not

of a line of troops, but of troops scattered over a deep area of ground. This is equivalent to ranging not on the near side of the target but on a point beyond the edge, and then using a short fuze. But when the principal portion of the target is the front edge or front line of troops, this method is inadmissible. For the trajectories of a number of shrapnel shell fired at a target do not coincide, but form a sheaf of fire, some being over and some short. If the mean trajectory passes through the front line of the target then the half which (if they did not burst) would pitch over are wasted, or nearly so, as far as the front line is concerned, and only the shorter half of the sheaf can be reckoned on for effect. And if we raise the trajectory so that three-quarters would pitch over, then the only shell effective on the front line will be the remaining quarter, which, if they did not burst, would pitch at the target or short of it.

Further, raising the trajectory reduces the width of the front line of the target covered. Taking the target as a six-foot zone drawn across the circular section of the bullet-cone, as in E, Fig. 80, then the number of bullets intercepted by the six-foot zone will be greatest when its centre coincides with the centre of the circle, and will decrease as the centre of the circle is raised above the target.

Density.

The question of the density of the bullet-cone in relation to the area of each individual unit of target is discussed in the chapter on Ranging.

The Angle of Descent.

This has already been referred to on page 210. But the practical effect of a small angle of descent will be more clearly seen on comparing the diagram of the shrapnel cones of the 15 pr. B.L. and the French gun.

In spite of the higher velocity and heavier bullet of the latter, the difference in the length of the cone is not very marked, the distances at which the bullets are effective being 330 yards and 280 yards respectively. This is due to the rapid falling-off in velocity of shrapnel bullets, most of the extra initial velocity being soon expended in overcoming the resistance of the air. But on comparing the depth of "beaten ground" we find that when both the shell are burst at the typical height, $\frac{3}{1000}$ of the range, the French shrapnel covers 280 yards in depth as against 120 yards for the 15 pounder B.L. This astonishing discrepancy is principally due to the difference in the angles of descent, which are 1 in 10 and 1 in $6\frac{1}{4}$ respectively. This comparison is however unfair to the 15 pr., as a better figure is obtained by bursting its shell 50 feet high instead of 27. But even in this case the depth is only 170 yards as compared with the French 280.

High versus Low Velocity.

In the French gun the angle of descent is flat enough to carry at least the top bullets of the shrapnel cone to the limit of their effective velocity before they strike the ground, whereas the 15 pr. bullets are

stopped with much of their effective velocity unexpended. And this leads us to a most important modern question, namely high versus low velocity. From a gun of given power and calibre we may either fire a heavy shell with a curved trajectory, or a light shell, like an express bullet, with a flat one. In the former case we get a large number of bullets, in the latter a small number; in the low-velocity gun we get more remaining energy in proportion to the strain on the gun, while in the other the high velocity soon dies away owing to the increased air-resistance and to the want of staying power of the light shell.

What, then, do we gain by increasing velocity at the expense of shell power?

We secure a small angle of descent, giving a deep dangerous zone and far-reaching shrapnel bullets. We facilitate ranging and minimize the effect of errors in range and fuze. And at deep targets we get a better distribution of bullets over the beaten area.

As against this, we lose a percentage of bullets proportional to the reduced weight of the shell. Say we lose 30 per cent. of bullets, we shall have to put 30 per cent. more guns in line to produce a given effect *in the same time*, provided that the guns are firing at their highest rate of fire. It is true that this rate is rarely attained on service; still, in battle it is the critical moments which count, and, other things being equal, it is not desirable to reduce the volume of fire which can be delivered on an emergency, as will be the case if we reduce the number of bullets.

Light versus Heavy Shell.

The effect of increasing velocity and reducing weight of shell will be best seen by comparing two extreme instances. Take a gun firing a 20lb. shell with a M.V. of 1500 fs. The muzzle energy is $\frac{20 \times 1500^2}{2g \times 2240}$ or 312 foot-tons. Take another gun of the same calibre with a M.V. of 2000 fs., firing a shell of $11\frac{1}{4}$ lbs. The muzzle energy is 312 foot-tons, the same as before, and the gun and carriage will be of the same weight as in the first case. That is, we shall have sacrificed 43.75 per cent. of bullets to get the extra 500 fs. velocity. In this case it is evident that the gain is not worth the sacrifice.

Correct Proportion of Weight to Velocity.

The muzzle energy, which is determined by the weight of the equipment, being the product of the weight of the shell and the square of its velocity, we have to decide on the best proportional value of these factors. Unfortunately, this is not a matter of exact science, but a question of tactics. For deliberate shooting at a standing target the powerful shell is to be preferred; for rapid shooting at a scattered or moving target the flat trajectory and far-reaching bullet-cone will give better results. In the European equipments introduced since 1904 there is a surprising uniformity in this respect, all being 14.3 prs. with M.V. of about 500 m/sec. But this may possibly be due to their being all supplied by only two firms, Messrs. Krupp and Messrs. Schneider,

Searching Power with Flat Trajectory.

It is sometimes urged as an objection to high-velocity guns that the trajectory is so flat as to pass clear over a crest line without searching the reverse slope. This statement however will not stand the test of arithmetic. For however flat the trajectory we shall hardly get an angle of descent of less than 5° at medium ranges, and few reverse slopes so steep as this are to be met with on service. And if we add to the angle of descent the semi-angle of opening, between 7 and 8 degrees, we get a "searching angle" of 12° to 13°, which corresponds to a slope which men would have to climb almost on their hands and knees. The maximum searching power is obtained when the angle of descent is equal to the mean reverse slope—say from 2 to 3 degrees, according to the country—and the flatter the trajectory the nearer we approach to this ideal.

CHAPTER XXV.

INDIRECT LAYING.

General Remarks.

The term *indirect laying* is applied to the methods of laying guns or howitzers in which they are not layed upon the target to be attacked by direct vision.

In this nature of fire the four principal methods of directing the gun are—

1. By an auxiliary mark, usually called an *aiming point*, for line, and by clinometer for elevation.
2. By direct vision for line, and by clinometer for elevation.
3. By an aiming point both for line and elevation.
4. By direct vision for elevation and by aiming point for line.

In the French Artillery indirect laying is normally used, even if the target happens to be visible from the guns. This latter method is sometimes but rarely applied in our service.

For instance, let the target be a battery on a hillside, visible but too indistinct to lay upon for elevation, and with a well-defined sky-line above it. Then the simplest procedure will be to order the battery to lay on the sky-line, deducting from the estimated range elevation the number of degrees by which the target is below the sky-line, which is measured by the Battery Commander with his scale held vertically at arm's length. The further procedure as regards ranging and fuzing is explained in the section on the Angle of Sight.

Or again, let the target be a long trench of which a portion only is clearly visible. Then the best results will be ensured by laying all guns on the portion visible and giving such deflection as will distribute the fire over the whole trench.

But in the great majority of cases where indirect fire is used the battery will be posted behind cover so that the target cannot be seen from the guns.

Fire from Behind Cover.

As a typical case, suppose the battery in action behind a hill, trees, houses. or other cover from view. The Battery Commander is posted sufficiently far to the front to see the target, and sufficiently far to a flank to be safe from prematures from his own guns and to allow the fire of the battery to be "switched" on to any probable target without obliging him to shift his post. From this point, known as the *observing position*, the Battery Commander commands his battery, either by telephone or by semaphore code.

The Battery Commander reaches his post about 10 minutes before the battery arrives. Before the battery opens fire, the Battery Commander has to determine the angle of sight, the range elevation, and the line. He should be able to complete these operations before the battery arrives, so as to enable it to open fire at once.

In many cases on service the Battery Commander will have time to calculate with deliberate accuracy the elevation and direction of his guns, so as to open fire without any error other than that due to weather variations, known as the error of the day. But these are not the typical conditions under which a battery comes into action. The Battery Commander must be able, when necessary, to form a rapid estimate of the initial elevation and direction to be given to his guns, in order to pitch his opening rounds close enough to the target to enable him at once to make the necessary corrections from actual observation. To make this rapid estimate with confidence and success it is absolutely necessary that the Battery Commander must understand the principles governing the determination of the initial angles of elevation and direction. When working with other troops, for instance, a vague guess at the displacement angle is likely to be as dangerous to friend as to foe. But if the B.C. thoroughly understands the process of measuring his angles, then this knowledge enables him not only, when necessary, to shorten the calculation by working in round numbers, but, which is more important, it teaches him which corrections may be neglected in any particular case, and which must be taken into account.

We will accordingly first discuss the theoretical considerations upon which the determination of the initial angles of elevation and direction—or, as they are styled in French, the "éléments du tir"—are based, and we will afterwards consider their practical application.

Theory of the Angle of Sight.

The use of the angle of sight in ranging a battery is a simple matter, which however is the source of more mistakes than arise over any other detail of practical gunnery.

When the battery is firing with clinometer elevation from behind cover at a target on a higher level, then the quadrant elevation which has to be given to the guns is the sum of the elevation required for the range and of the elevation of the target above the gun, or angle of sight. And when the correct elevation has been found, then the fuze corresponds, not to the corrected quadrant elevation, but to the elevation due to the range—that is, the corrected quadrant elevation less angle of sight.

For instance, suppose a battery with old pattern sights in action behind cover at a target distant about 3000 yards, and 450 feet higher than the battery. Then the angle of sight is about 3 degrees. The elevation for 3000 yards, according to the range table, is 3° 45′. This elevation would carry the shell to a point 3000 yards from the gun, and on the same level. To reach a point 3° higher we must give 3° more elevation, making 7° 45′ clinometer elevation. 4° 45″

Suppose that the Battery Commander ranges as follows—

7° 30′ (−)	...	8° 10′ (+)
7° 40′ (−)	...	8° (+)

Then the probable elevation is about 7° 50'.

But 3° of this is angle of sight, and only 4° 50' range elevation; therefore the fuze will be that corresponding to 4° 50'.

Next suppose that the range takers give the range as 4200 yards, and that the angle of sight is 2 degrees depression. The elevation corresponding to 4200 yards is 7° 45'. 7° 45' clinometer elevation would carry the shell to a point A 4200 yards distant and on a level with the gun.

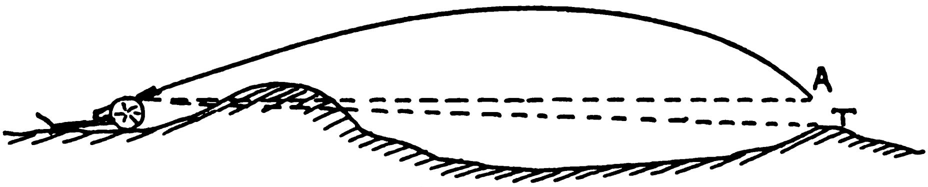


Fig. 84.

To reach point T we require 2° less elevation; therefore the clinometer elevation is 5° 45', and the Battery Commander ranges as follows:—

5° 30' (—)	...	6° (+)
5° 40' (—)	...	5° 50' (+)

Then the probable clinometer elevation is 5° 45', and the elevation due to the range 2° more, or 7° 55'; therefore the fuze will be that corresponding to 7° 55'.

The above examples refer to the old pattern equipment, in which clinometer elevation cannot be given on the ordinary sights. They are given here because it is necessary for the proper handling of modern sights that the officers using them should understand the principle on which the design of these sights is based.

With the Q.F. sight, in which the yard scale and clinometer are combined on the same sight-bar, and with the independent line of sight, the Battery Commander is saved the trouble of adding and subtracting the angle of sight. Thus, in the first instance he would simply order "Angle of sight 3° elevation, 2900, 3200, Echelon corrector 170, increase 10," and, having found range 3100, "Echelon 3100."

The effect of the Battery Commander's order, "Angle of Sight 3° elevation," is that the adjustable level of the sight is set at 3° elevation; the laying number then elevates the gun and sights 3 degrees, till the bubble is centred, and the elevating number gives the elevation for 3100 yards in addition to the 3 degrees.

Aiming Points.

When a gun is layed direct at an aiming point above or below the target instead of on the target itself, the question of the angle of sight again arises.

Thus, suppose that an enemy's battery can be made out on a hill-side with glasses, but is not clear enough to lay on, and that there is a clearly defined tree on the sky-line above it. The Battery Com-

mander measures the vertical angle between the tree and the target with the director, or with a scale held at arm's length, or simply with his knuckles. (Every officer should know the angles subtended by his own knuckles.) He then directs his layers to set the angle of sight on the adjustable sight-level and lay by clinometer elevation, using the tree only for line.

But with the old pattern sights, the Battery Commander would have to use open sights and direct laying on the aiming point, and, having found his range, would have to make allowance for angle of sight when ordering the fuze.

The Measurement of the Angle of Sight.

When a contoured map is available upon which the position of the target and of the battery can be located, the angle should be measured directly from the map. Thus, Battery ¼ of the way down the slope between the 400 and the 350 contours; target on the 600 contour distant 4500 yards. "Reduce the error to inches and divide by the number of hundreds of yards in the range;" then

$$\begin{aligned} \text{Angle} &= \frac{225 \times 12}{45} \\ &= \frac{45 \times 5 \times 12}{45} \\ &= 60 \text{ minutes elevation.} \end{aligned}$$

Where no map is available, the angle of sight is measured from the observing point with the level on the director.

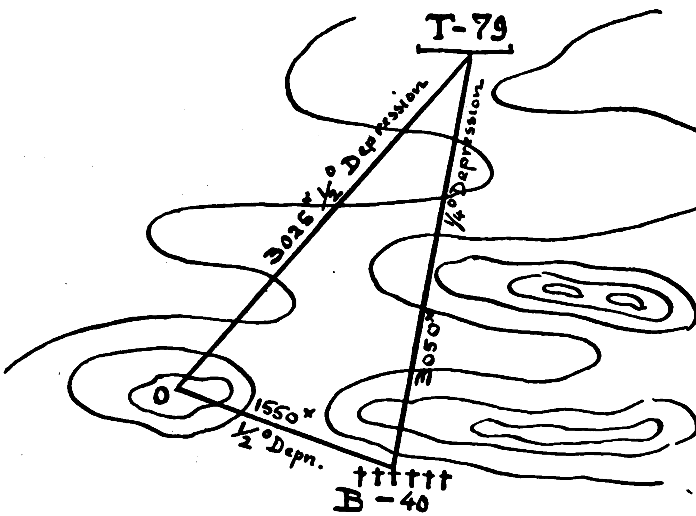


FIG. 85.

With old-fashioued directors this had to be found by calculating the relative heights of the target T and the battery B with respect to the observing station O, as in Fig. 85. With a modern instrument it is merely necessary to incline the base-plate of the director so that it is in the plane of the three points TOB, set the director telescope

to the angle TBO, and read off the gun angle of sight on the level attached to the telescope. The angle TBO, known as the battery angle, is found with the plotter as afterwards described.

Choice of Observing Position.

This has already been referred to on page 197. It is desirable to choose an observing position on the same level as the guns, in order to enable the angle of sight to any point to be read off directly without the use of the plotter.

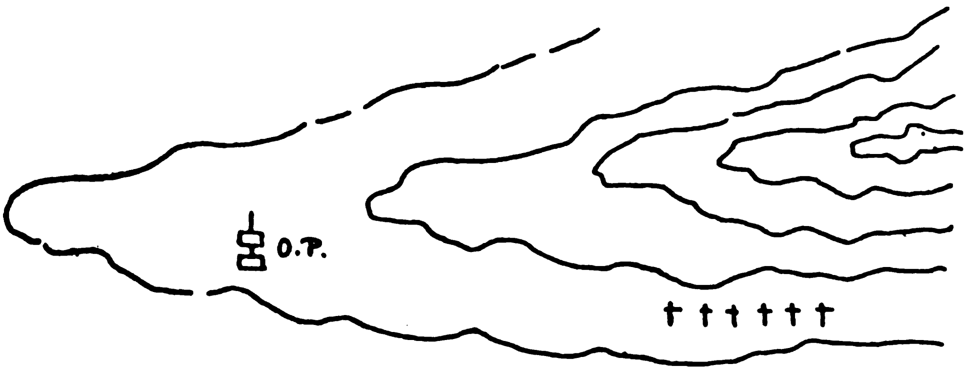


FIG. 86.

Thus in the figure the Commanding Officer is posted on the shoulder of the hill, on a level with the battery and at the same distance from the target. By standing on a wagon he is able to see over the ridge in front.

Measuring the Range.

The distance from gun to target is found by direct measurement from the map, or by measuring the distance from the observing position to the target and to the battery with the range finder, and combining the results with the field plotter, described on page 95.

Say that the distance from observing point to battery is found to be 370 yards, and that from observing point to target 3400 yards, the included angle, measured with the director, being 120°, Set the base scale at 370; set one arm at 120°, and slide the screw clamp which connects it to the other arm to 3400. Then the length of the other arm will give the range from battery to target, and the angle of the other arm the angle from the battery between observing point and target. For simplicity these graduations are marked on the reverse side; therefore, having set it, turn it over and read off the range and the angle. This ingenious arrangement is useful in avoiding mistakes.

Finding the Line.

If the "forward covered position" is selected, the line is best obtained by standing on a wagon limber behind the gun, or upon the gun itself, and laying out one aiming post in front. If the "retired covered position" is selected, as will usually be the case, there are several methods of getting the line. The principal are:

(*a.*) Director.
(*b.*) Two aiming posts and director.
(*c.*) Two directors.
(*d.*) Compass.

Pages 219 and 221.—It is now laid down that the director is always to be set up with the zero towards the target. This simplifies the procedure, and renders it unnecessary for the B. C. to trouble about the supplementary angle.

follows. Set up the director with 180 towards the guns, clamp it at zero, and lay on the target. Order "All guns lay on director." Unclamp the director and align it on

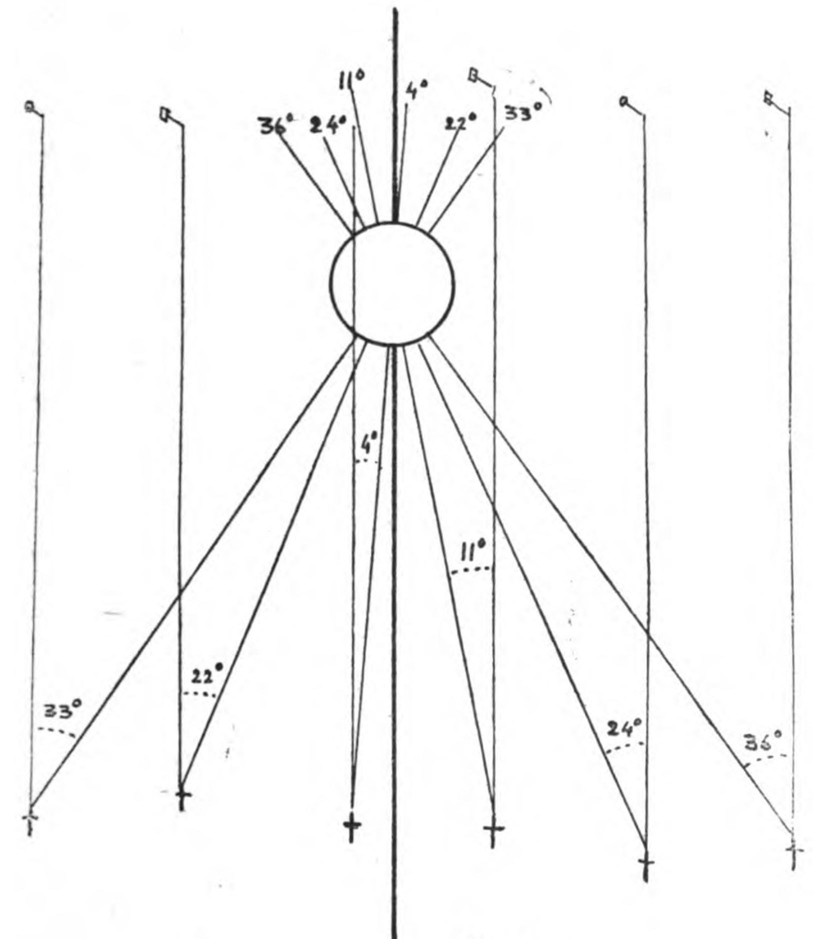


FIG. 87.

each gun in turn, and call out (or write down) the reading of the arrow head, as Fig. 87. When the guns are layed on the director at these angles, they will all be parallel.

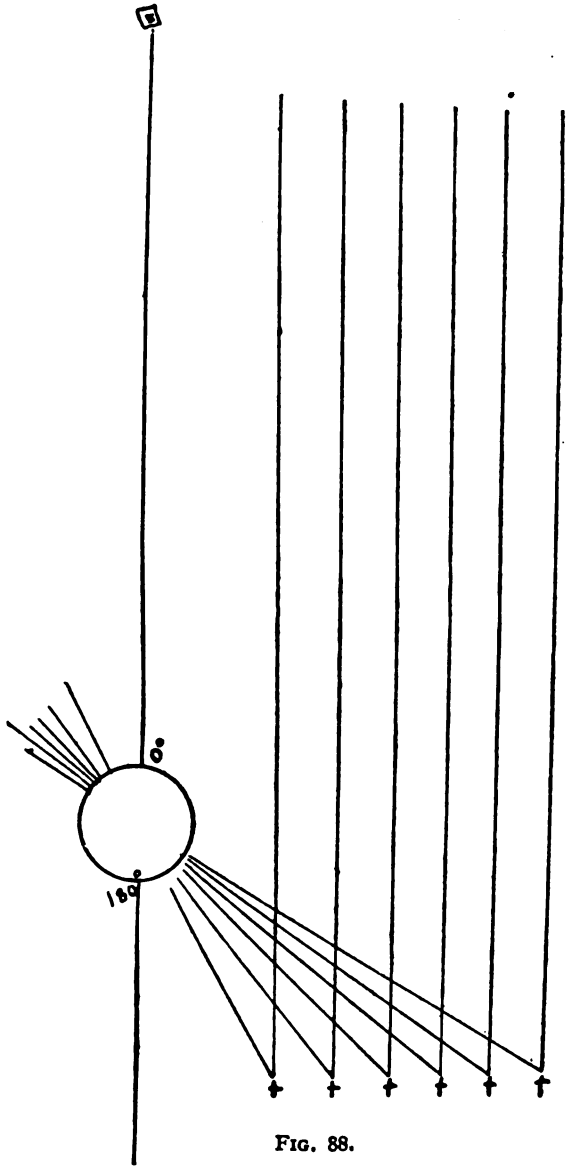


FIG. 88.

If the director is outside the flank of the battery, the guns will be off the target, as in Fig. 88. If the ground is such that the distance of the director right or left of the centre of the battery can be measured or estimated with approximate accuracy, then the error can be eliminated by laying the director an equal distance off the target when originally set up; thus if the director be 200 yards right of No. 3 gun, lay it on a point 200 yards right of the centre of the target, and then point it at the guns and give out the angles. But

practical experience shows that guessing the distance right or left of an invisible line of fire is a method subject to considerable error, and that when the conditions are at all difficult it saves time and ammunition to use two directors and the plotter, as in (*c*).

(*b.*) *Two Aiming Posts and Director.*

Instead of setting up the director in sight of the target, mark the line to the target, from a point as near as possible to the battery, with two aiming posts; set up the director in prolongation of this line, and proceed as in (*a*). This method is tactically sound, as entailing the minimum of exposure.

(*c.*) *Two Directors.*

At a practice camp the covering crest is usually a bare ridge over which it is easy to lay out a line of fire. On service the cover is more likely to consist of trees, houses, or ground over which the view is obstructed by hedges or enclosures. It is then necessary to give the line from a point which may be half a mile from the guns. The procedure is as follows: Set up the first director at point O, with the 180° towards the target. (It may be either in view of the target or, better, in line with two aiming posts.) Set up the second director at a point B, near the guns and visible from O. Work out the battery angle TBO with the plotter: signal this to B; set the second director to the battery angle, and lay it on the first director. Then when unclamped and turned to zero the second director will be pointing at the target, and the line is given to each gun as in (*a*). If the second director is in front of the guns, it should be layed *back* on the first director, or else set at the supplement of the battery angle, in order to bring the 180° towards the guns.*

If for any reason the plotter is not used, the second director may be set at the angle TOB (which would bring them both parallel) less the *displacement angle*. This is the angle due to the lateral distance of the first director from the line of fire, and is obtained from the following table:

DISPLACEMENT TABLE.

Distance of Director from Line of Fire.

100ˣ	at	2000	yards	range	= 3°
„	„	3000	„	„	= 2°
„	„	4000	„	„	= $1\frac{1}{2}$°
„	„	5000	„	„	= $1\frac{1}{4}$°
„	„	6000	„	„	= 1°

*It is not sound for the B. C. to send down the supplement of the battery angle. For if he cannot see the guns, he cannot be certain whether the second director is in front of them or behind them. He should confine himself to sending down the battery angle, and leave the rest to the battery leader.

An instance of the use of two directors in cramped ground is shown in Fig. 89.

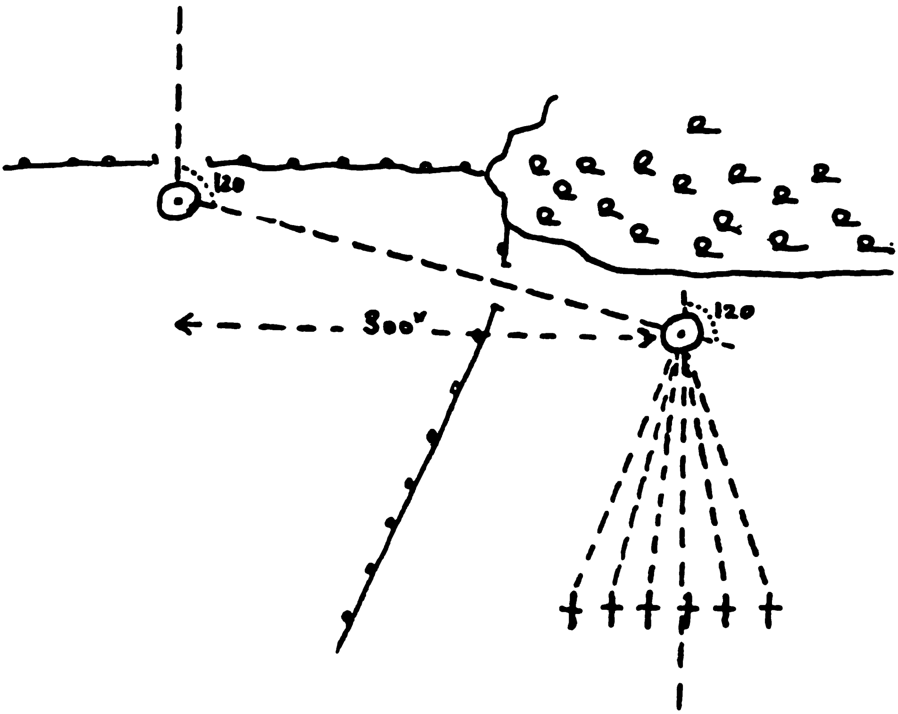


FIG. 89.

The displacement being only 300 yards, the plotter is not used, but the first director is pointed 300 yards left of the target, and the second director set up parallel to it. This enables the line to be laid out without waiting for the rangetakers, who would probably be delayed by the difficult ground.

(d.) The Compass.

Every modern director is fitted with a compass needle which enables it to be oriented. If two directors be both set up with the zero to the North, and if both be then set to the same angle, they will be parallel. The displacement correction can be given as in *(c)*. The compass is most useful in woodland country and for night work.

Use of the Dial Sight.

It must be remembered that the dial or panorama sight is a director in itself and can be used to replace the battery director. Thus in *(b)*, one gun may be run into line with the aiming posts, and is then available to give the line to the other guns. Or if one gun is out of sight of the director, it can always get its line from the next. Thus if No. 1 gun has the line, the layer of No. 1 lays *back* on the dial sight of No. 2, and calls out the angle; No. 2 gun lays at this angle on the dial sight of No. 1, and is then pointing at the target.

The Aiming Point.

There are two distinct ways of using an aiming point; first, to get the line, and, second, to keep it. Thus, suppose that the director is visible from one gun only, while all can see a steeple to the left. Then it may be convenient to measure the battery angle to the steeple instead of to the director, and to give this angle to the guns. This may be done with the plotter, as afterwards described, or with the displacement table. But it must be remembered that if all the guns be layed at the same angle on the steeple, they will not be parallel unless the steeple is square to a flank.

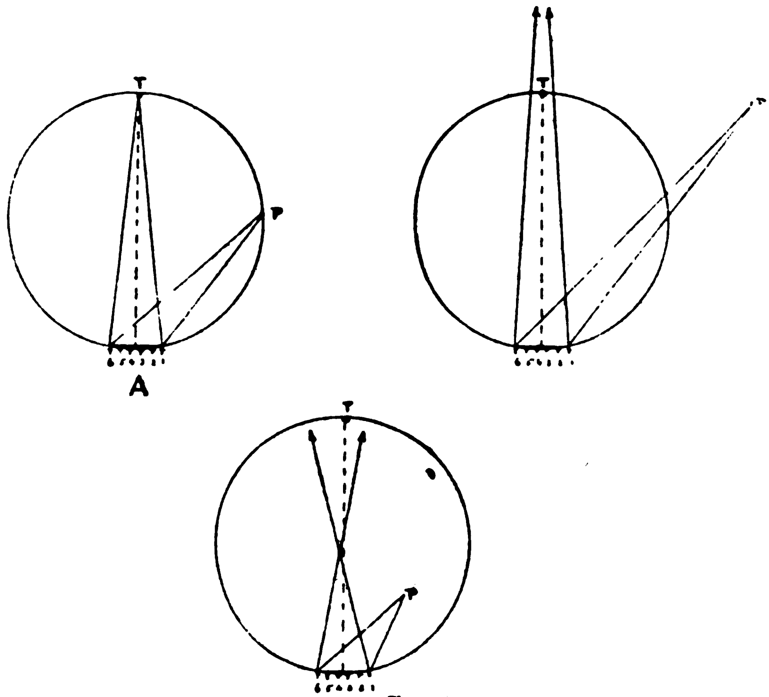


FIG. 90.

If the steeple be on the circumference of a circle having its centre in the line of fire and passing through the battery and the target, as at A, Fig. 90, then the lines of fire will converge at the target. This follows from the geometrical proposition that angles in the same segment of a circle are equal. If it be without this circle, the lines of fire will converge beyond the target; if within it, they will cross at a point short of the target.

Since it tends to confuse observation of fire if the shell from the right gun are pitching on the left of the target, and vice versâ, the aiming point should when possible be chosen outside the above-mentioned circle. And the battery commander must remember that if his aiming-point be distant in comparison to the target, or if it be square to a flank, the effect will be to distribute fire from the first round. This must be taken into account in ordering deflection.

It will rarely be desirable to choose an aiming point in rear of the battery, except at a very wide target, since such an aiming point gives diverging lines of fire.

To obtain parallel lines of fire with an aiming point which is not square to a flank, one of two methods may be used.

Page 224.—When using the plotter as in (*a*), the angle should, strictly speaking, be worked out for the centre of each flank section. In the Table it is assumed that the front of the battery is at right angles to the line of fire. The true correction is that due to the angle between the aiming point and the perpendicular to the front of the battery.

Angle between target and aiming point. Degrees.		Correction in minutes for each section, for an aiming point distant yards:					
Correct Outwards.	Correct Inwards.	2000	3000	4000	5000	6000	7000
0	180	72	48	36	29	24	21
10	170	70	47	35	28	23	20
20	160	68	45	34	27	22	19
30	150	62	41	31	25	20	18
40	140	55	37	27	22	18	16
50	130	46	30	23	18	15	13
60	120	36	24	18	14	12	10
70	110	25	16	12	10	8	7
80	100	13	8	6	5	4	3
90	90	0	0	0	0	0	0

For instance, if the Right Section be the ranging section, and the aiming point be 50 degrees from the right hand end of the target and distant 3000 yards, the order to the Battery would be:

"Aiming point Church steeple."
"Right Section line of fire 50 degrees left."
"Centre ,, ,, 50 ,, 30 minutes left."
"Left ,, ,, 51 ,, left."

Between 80° and 100° the correction is so small as to be negligible, and endeavours should always be made to obtain an aiming point within these limits.

It must be remembered that the accuracy of these corrections is dependent upon the guns being at correct intervals and in dressing. The latter is especially important when the Battery Leader is obliged to use an A.P. within 2000 yards of the battery.

Next as regards the method of using an aiming point to keep the line when already obtained by the director.

Even with a panorama sight, the director may not always be the most convenient point to lay on at each round. Or the B.C., having

*The geometrical demonstration of the formula on which this table is based was given in the last edition of this book. It is now omitted, as being of no special interest. Any officer can work it out for himself, remembering that angles in the same segment are equal.

given the line to the guns, may find it necessary to remove himself and his director to a better position for observing. It is therefore a good plan to train the layers to pick up a conspicuous distant aiming point themselves as soon as they have got the line, and to record the angle to this point in chalk on the shield. Aiming posts may have to be used if the aiming point is liable to be obscured; but they are less accurate, since even an anchored gun is liable to shift during firing so as to throw out the line.

Distribution of Fire.

The guns being normally layed parallel, then if the target be wider than the front of the battery it is necessary to open out the lines of fire of the guns or of the sections to cover it. This is best done by direct observation. A formula for this, with a table based upon it, was given in the last edition of this book. It is however undesirable to carry about tables to work problems which an officer can solve by looking over his knuckles, and the table has therefore been omitted.

Concentration of Fire.

It is sometimes desirable to concentrate the fire of all the guns on one point of the target for ranging or for demolition. This is done by ordering, for instance, "Concentrate 20 minutes on No. 1." Then No. 2 gives 20 minutes more right, No. 3 gives 40 minutes, and so on. The amount of the concentration angle is the angle subtended by 20 yards (the gun interval) at the target. This may be calculated by the gunner's rule, or may be obtained from the displacement table; thus 100 yards subtends 2 degrees at 3000 yards, therefore 20 yards subtends 24 minutes.

Switching.

The quick and accurate switching of the fire of a battery from one target to another, when firing from the covered position, is a matter of great importance.

Suppose that a new target appears; the battery commander, from his observing station, turns his director on it, and finds it to be 30 degrees right of the old one. Then it does not follow that "all guns 30° more right" will bring them on to the target.

In Fig. 91, let T be the old target, U the new one. Then it has been demonstrated by Major G. H. Geddes that T B U, the switch angle, is equal to T O U + O U B − O T B. In other words, the switch angle is obtained by taking the angle between the two targets from the observing position, adding the apex angle U at the new target, and subtracting the apex angle T at the old one. (If the new target be on the far side of the battery with respect to the observing position, then T must be added and U subtracted.)

The practical difficulty in using this method is the determination of the apex angle. The displacement of O with respect to the lines of fire B T and B U has first to be estimated, and these estimates are subject to considerable error. In most cases it will be found best to work out a fresh line to the new target with the plotter. Under

easy conditions, the switch angle may be obtained by laying the director off the new target by the amount of the estimated displacement.

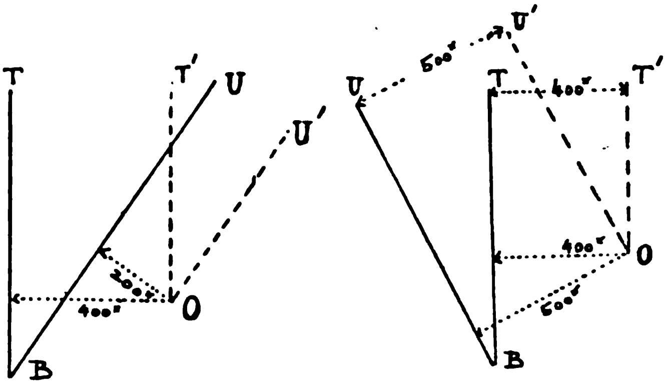


FIG. 91.

Thus in Fig. 91 the director is first layed on T′ to get the battery angle to the old target, and then on U′ to get the battery angle to the new target; the difference is the switch angle.

*Methods of Using the Plotter.**

We have already described the use of the plotter as a range-finder. An even more important application of it is its use for finding the line.

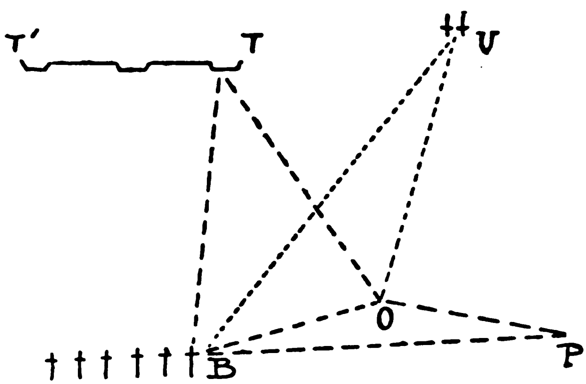


Fig. 92.

The battery being posted as in Fig. 92, the plotter may be used in any of the following different ways:

(*a*) Solve the triangle TOB; this gives the angle TBO, which fixes the line from the battery to the target with reference to the observing position, O.

*NOTE.—Lieut. Sebag-Montefiore's plotter card is a compact table for the solution of the triangle TOB, based on the ratio of the range OT to the base OB. It is quicker to use than the plotter, but not so simple. It can be obtained from the publishers of this book.

(*b*) Solve triangles TOB, POB; then the sum of the angles TBO, PBO, is the angle TBP, which fixes the line from the battery to the target with reference to the aiming point, P.

(*c*) To save the trouble of taking the range to P, the angle PBO may be observed from the battery and sent up by telephone.

(*d*) To find the angular width of the target T'T from the battery, solve the triangles TOB, T'OB: the difference between the angles TBO, T'BO is the angular width required.

(*e*) To switch on a fresh target U, solve the triangle UOB; the difference between the angle UBO and the battery angle TBO already found is the true switching angle.

(*f*) To engage a wide target oblique to the line of fire, find the range and line to each end with the plotter.

The plotter may be used without a rangefinder with considerable accuracy. Suppose the range 4250, base 610, and angle 120°; then if the range be judged 3800 and base 550 (both too short) the error in the battery angle will be less than ¼ degree. If the range be judged 4500 and base 700 (both too long) the error will be under ½ degree. And if the range be judged 4500 and base 550 (one too long and the other too short) the error will still be only 1¼ degrees.

Laying by Map.

This is an excellent method when a large-scale ordnance map is available, as would be the case in home defence. The practical difficulty lies in locating the three points TOB on a small-scale map such as would be used on service.

Laying by the Sun.

This method was found useful by the Russian batteries in Manchuria, when in action among high crops. It may occasionally be useful when it is neither possible to see the guns nor the battery leader's director from the observing station.

Set the director at zero, and align it on the target. Unclamp, traverse the sight-bar till the shadow of the fore-sight falls in line with the back-sight, and read the angle. Send down this angle, minus the displacement correction, to the guns, and let the guns lay on the sun by the shadow of the fore-sight of the dial sight in the same way and at the given angle.

Then the guns will be pointing at the target. Each gun can now pick up an aiming point. The guns must be ready to lay at once when the angle is sent down, as the sun moves ¼ degree per minute. This method can only be used when the sun is fairly low in the sky. The moon or a bright star can be used as an aiming point in the same way. It is as well to repeat the process in order to ensure accuracy.

Laying on a Search Light.

This is easy if a piece of thin paper be held close in front of the back-sight notch. The shadow of the fore sight is visible through the paper,

PRACTICAL APPLICATION OF THE PRINCIPLES OF INDIRECT LAYING.

In the foregoing paragraphs we have discussed a variety of methods of laying for line and elevation from the covered position. An officer fully conversant with these will be able to direct the fire of his battery even in the most awkward situation. But the officer's skill and judgment should be directed rather to avoiding awkward situations than to coping with them. Since a fault in any one link of a chain of operations may spoil the whole, it is as well to make the chain as short as possible.

In any given situation the B.C. should select the simplest and easiest way of directing the fire of his guns. When his observing position is within speaking distance of the battery, his best method is to give each gun the line with his own director. When farther distant, it will be found that in most cases the two-director method is the best. The battery leader then gives each gun its line as soon as it is unlimbered, and the layers select their own aiming points. If the guns are up before the B.C. has completed his calculations, he should give them an approximate line of fire to go on with.

Displacement is best given with the plotter; under exceptionally easy conditions the method of laying the director off the target may be used.

Under difficult conditions the B.C. can always fall back on the compass. Thus if he has to observe from the front of a thick wood, with the battery behind it, or from a window of a house, the compass, the map, and the sun will be the only possible means of laying out the line.

It usually saves trouble to send the battery staff horseholders to mark the flanks of the covered position. And when the ground is bad, it is invariably sound to fall out the section commanders and Nos. 1 to select emplacements for their guns. This applies especially to howitzers, whose shooting is affected by bad platforms.

It must be clearly understood that when the battery is in action under cover and the Major observing from a point 800 yards to the right front, the Major always retains command of the battery, and never subsides into a mere observing officer. He gives all executive orders just as if he were standing beside the battery.

The fact of the Major observing does not preclude the use of an additional observing party to the right or left front, whose duty, if employed, is to keep the Major informed of the effect of his fire. If the tactical conditions permit of the establishment of such a party in a position where they have a good view of the target they may be of the greatest use.

F.A.T., 1908 also allows an alternative method, in which the Major remains under cover with his battery while a junior officer ranges it. But the cases which would justify the Major in abandoning direct

personal touch with the battle, and delegating his most important duty—the observation of the course of the combat, and corresponding control of his fire—to a subordinate, must be considered exceptional.

Duties of Battery Leader.

Except when the Major gives the line to each gun himself, he must rely on the battery leader to give him parallel lines of fire. Starting with these, the Major can give the necessary orders for concentration or distribution. The Battery Leader, being on the spot, must be left to select the best method of giving the line to individual guns. The Major merely sends him down the battery angle; the Battery Leader may give the line to each gun, or to one gun which gives it to the others; or he may order an aiming point, giving corrections for parallelism by the table; he may even have to lay out his line with aiming posts, and then shift his director to a more suitable place in the same line. Provided that the guns can reach the enemy, no technical difficulties should stand in the way of their being layed on him.

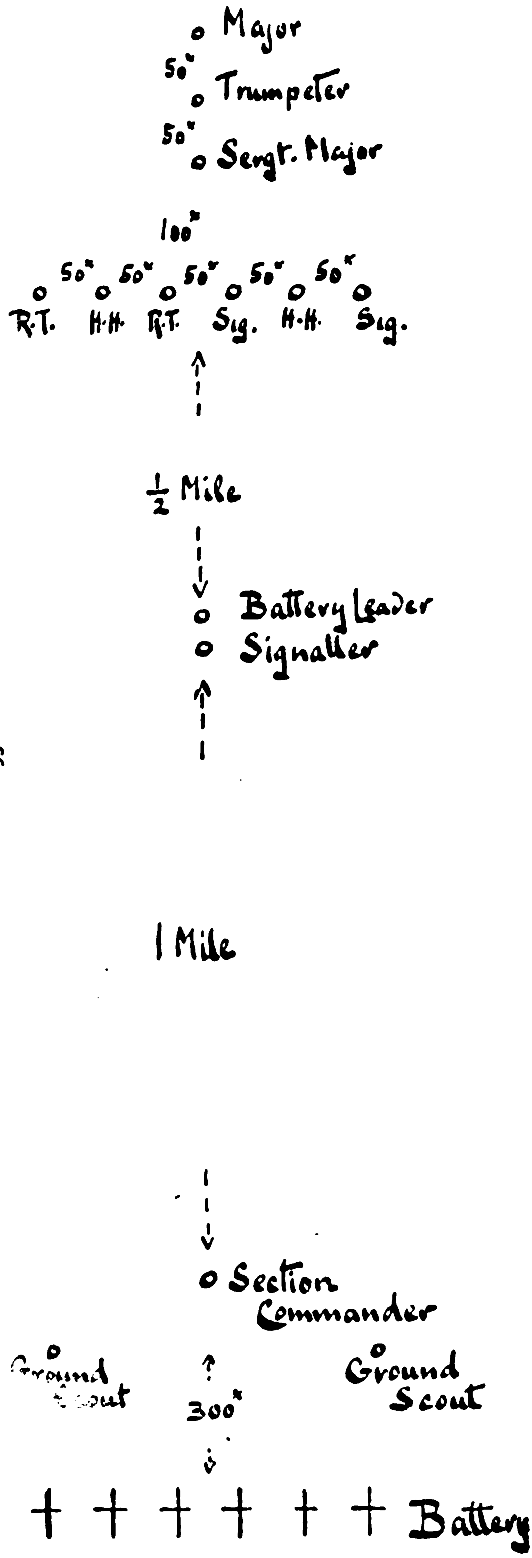
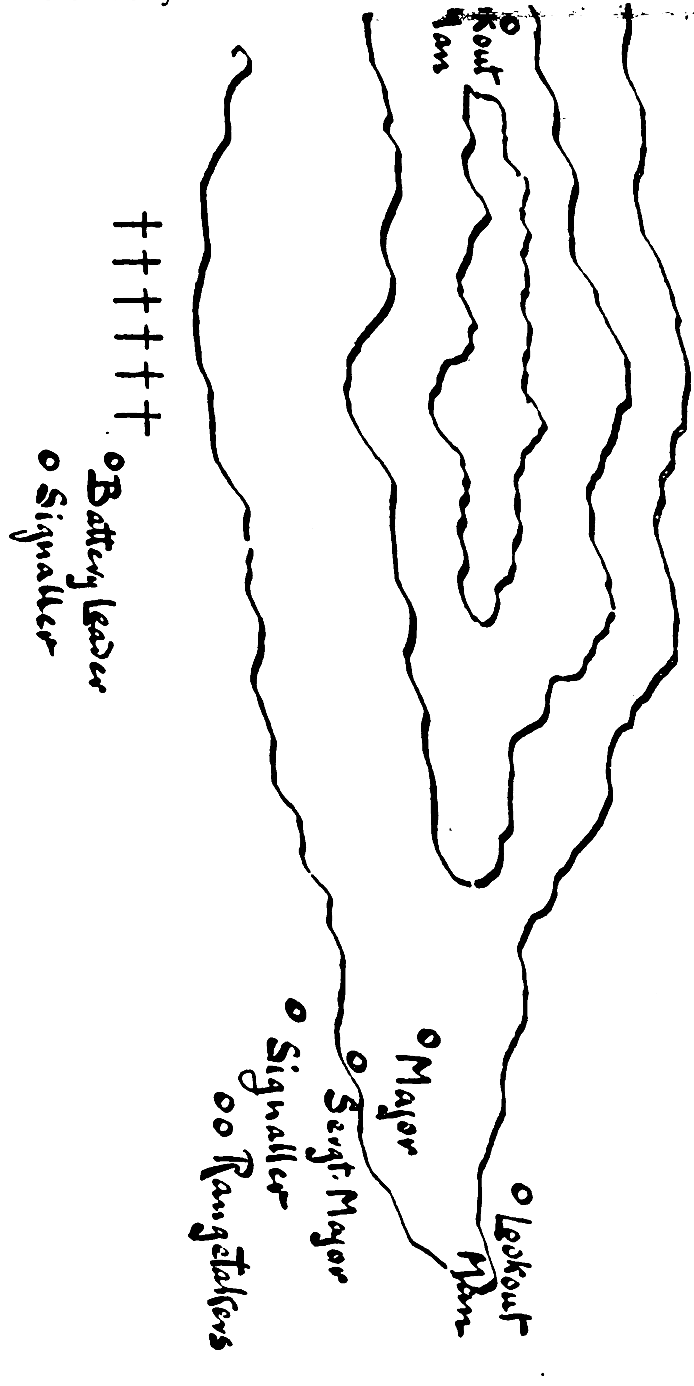


FIG. 93.

DISTRIBUTION OF BATTERY AND STAFF DURING ADVANCE INTO ACTION. OPEN COUNTRY.

Pages 230, 231, Plates.—The B. C. is now accompanied in his advance by a section commander and by the two look-out men. The battery staff follow as a closed body. In action in the concealed position, the normal position of the B. L. is in rear of the centre of the battery.



DISTRIBUTION OF BATTERY IN ACTION.

FIG. 94.

Preliminary Line.

This is sometimes termed a *datum line.* When no target is visible, the line is laid out to a conspicuous feature *(datum point)* in the presumed direction of the enemy. A rough panorama sketch which need consist only of 3 or 4 lines is then made; the angle of sight, gun range, and switch angle are th

Page 232.—The B. L. no longer gallops up to the B. C.; either he is with him already, or the S. C. who accompanied the B. C. is sent to the B. L. with all necessary information. The exact position of the limbers is selected by the Captain, who should if possible first join the B. C. to find out the direction of the enemy.

1. Battery Commander receives his orders, reads them to officers, battery staff, and Nos. 1. and informs them where he intends to go.

2. He advances with Staff as in Fig. 93.*

3. He arrives at his position, reconnoitres the enemy, selects his observing position, the position for the battery, and the general direction of position for limbers.

4. He proceeds to the observing position, where the rangetakers have in the meantime set up the director and are taking the range. He sends the horseholders to mark for the flanks of the battery.

5. The two signallers lay out the telephone wire from the observing position to the position of the battery, working from the centre outwards.

6. The battery leader gallops up, followed by his signaller; the B.C. points out to him the position of the battery and the direction of the target.

7. The battery leader brings the battery into action as in Fig. 94 The limbers proceed towards the position selected by the Battery Commander.

8. In the meantime the B.C. measures the angle of sight and sends it down to the battery. He also sends down the approximate battery angle.

9. The rangetakers having in the meantime taken the range to the target and to the battery, the B.C. works out the battery angle and the range with the plotter. He sends down the correction to the approximate battery angle ("all guns 1½° more Right.")

10. The B.C. orders the ranging section, the nature of shell, and the corrector, and sends down the two elevations to the ranging section.

11. The ranging rounds are fired, and the B.C. holding his deflection scale at arm's length, measures the angle of the fall of the shots right or left of the target. He sends down the deflection correction and orders a fresh elevation or elevations. ("All guns 30′ more right. 4500-4600.")

* The Staff now follow as a closed body. See F.A.T., 1908, page 186.

12. The B.C. orders a further deflection correction if necessary, and a fresh elevation. If the target is bracketed he orders a fuze echelon.

13. On the result of the echelon the B.C. gives the corrector setting and the final elevation, and orders the method and rate of fire.

14. Should the target be visible guns, the B.C. orders "corrector — one round battery fire 10 seconds." He notes the error of each gun, which is recorded by the signaller. He sends down the six corrections thus: "Number 1, line. Number 2, 10 minutes more left. Number 3, 30 minutes more left. Number 4, doubtful. Numbers 5 and 6, line. Fire Number 4 again."

15. Number 4 gun having been fired again, the B.C. gives "Number 4, 50 minutes more right. Section fire 10 seconds."

16. To switch on to a fresh target, the B.C. orders "Empty guns. Angle of sight 1° elevation. All guns 7° more right. Ranging section 3800-4100."

The procedure is then as before, except that, the error of the day of the fuze having been determined, there is no necessity to fire a fuze echelon.

The above procedure may appear complicated. But if every detail of it has been so thoroughly practised as to make it a matter of routine, like harnessing up a horse, the whole operation will go off smoothly and with less mental strain to all concerned than one of our old drill evolutions, such as "change front right back on number 4."

There is one point which should not be forgotten, and that is the concealment of the B.C. and his Staff—the "brain of the battery." Under ordinary tactical conditions the enemy will probably be able to locate the battery, though invisible, within, say, a quarter of a mile. Then enemy will keep a bright look out for the B.C. and will fire on any likely observing point. It is therefore advisable for the B.C. not only to keep under cover, but to avoid selecting any *conspicuous* observing position. It by no means follows that the point at which the director is set up is the best position to observe from.

Pages 233, 34.—The present method of ranging in our own service is described in amendment below, relating to F.A.T., 1913.

In Germany, the normal method is now section ranging, with a fuze such as to give 50% of bursts on graze. Fire for effect is commenced at 3 elevations.

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CHAPTER XXVI.

RANGING.

FIELD ARTILLERY TRAINING, 1913.
(PROVISIONAL).

Material. The 18 pr. time fuze is now considerably more accurate, the error being now only 48 yards at 2000 yards instead of 77 yards with earlier patterns. The effective points of burst are therefore as follows:

2000 yards	-	80 yards short.
3000 ,,	-	70 ,, ,,
4000 ,,	-	60 ,, ,,
5000 ,,	-	55 ,, ,,
6000 ,,	-	50 ,, ,,

The new straight-bar fuze indicator, when set to "corrector 150," gives these distances of burst under normal conditions. These correspond to an angular height of burst of 10 minutes. The spread of 18-pr. shrapnel bullets is about 40 per cent of the distance of burst.

The new director can be inclined so that the base-plate is in the plane of the three points TOB (see page 96). This enables the gun angle of sight to be measured without calculation.

Fire Discipline. The normal method of ranging the 18-pr., now called "collective ranging," is with time shrapnel, fired by "half-battery triplets." The right half-battery is loaded and layed at (say) 3000, with a corrector such as to give low bursts. The three rounds are fired in rapid succession, and, if "short," the left half-battery is loaded and fired at 3300. This being "over," the next triplet is fired at 3200; if "short," this gives the 100 yards' bracket; if "over," the 3000-3200 bracket thus obtained is subdivided by a fourth triplet. Fire for effect is then at once commenced at the mean of the 100 yards' bracket, as the corrector setting for effective height of burst will have been obtained in the process of ranging. If it is necessary to fire a fuze echelon to find the corrector, this is to be done before ranging is commenced.

In four-gun batteries, the 3 right guns are fired at the same elevation and fuze.

Ranging by a single gun, by a section, and by all guns, may be employed at the battery commander's discretion.

the length of the total rectangle of the gun.

B. Never trust a bracketing series of which only one round is plus or only one round round minus.

With regard to "A," it must be remembered that under service conditions the total rectangle will probably be twice as long as the theoretical total rectangle of the gun. This is due to inevitable small errors in laying, and to difficulty in distinguishing the target. F.A. Training therefore wisely ordains that under ordinary circumstances the interval between the first two ranging rounds is to be 300 yards.

With regard to "B," we have seen that it is advisable to repeat a single plus round or single minus round, even if clearly observed, before finally accepting the result of a bracketing series. This is absolutely necessary when observation is at all indistinct. It is a common error to suppose that any mistake in the long bracket will necessarily be discovered when the two verifying rounds are fired. At a service target, such as an irregular line of infantry lying in the grass, it is extremely difficult to determine whether a group of verifying rounds, pitching near the target, is under or over, and the consciousness of this difficulty is apt to make a Battery Commander assume, against his better judgment, that his verifying series is successful, though the soundness of his long bracket may be more than doubtful. Of two evils it is better to expend time and ammunition on getting a thorougly reliable long bracket, and then to "jump" the range and fuze, than to hastily assume the accuracy of the long bracket and have to expend twenty rounds in correcting it. The latter procedure is by no means uncommon at practice camps, when it is passed over with a few pungent remarks from the camp staff; on service it might lead to the loss of a battle.

Creeping.

Suppose the Battery Commander orders "both guns 2300," and observes both rounds a long way short; if he then proceeds successively to 2600, 2900, 3200, 3500 (over), 3400, 3200 and 3250, this is called *creeping.*

Creeping is less common since F.A. Training, 1903, has laid down that the normal interval between the original ranging rounds is to be at least 300 yards. It involves a great waste of time and ammunition. In the above case the B.C. would have done much better to make a 1000 yards bracket, proceeding to 3300, 3000, 3300 (repeated), 3100, 3200, and 3250.

When one round of the long bracket is clearly observed to fall close to the target, it saves time to make a 100 yards bracket, *repeating that round.* This is laid down in F.A.T. Thus if 2900 is observed just over, the next two rounds should be 2800—2900. Or if 3000 is observed just short, the next two should be 3000—3100.

Special Conditions.

It very frequently happens that all shell which fall (say) over the target are lost to view. This would happen, for instance, in firing at guns at the edge of a wood. In such a case there is nothing for it but to get a reliable pair of rounds short, "creep" forward till the shell again begin to disappear, and then verify.

Ranging Traps.

These are of many kinds. But the commonest and most dangerous trap is a deep hollow in front of the target. By the time the smoke of the bursting shell has risen to the level of the line of sight it is so thin that the target shows through it, and the appearance is very much as if the shell had burst over.

Another common trap is a ridge rising to the level of the target, say 200 yards in front of it, with an intervening hollow. Shells which fall into this hollow disappear and are judged over, while shells bursting on the ridge appear to be "range."

No "dodge" has ever been invented to avoid such traps. There is nothing for it but patient and conscientious adherence to the greatest of all ranging rules, which may be thus stated—

DO NOT ATTEMPT TO OPEN FIRE FOR EFFECT TILL YOU HAVE ESTABLISHED A THOROUGHLY RELIABLE LONG BRACKET.

FIG. 95.

Study of Ground.

Although there is no "dodge" which gets over the difficulty of ranging on a deceptive target, it is often possible to infer the existence of a trap from an intelligent study of the ground. Thus, in the annexed rough sketch, it is obvious that a hollow runs behind the ridge with the pine trees on it. An old hand at ranging would immediately recognise the possibility of the guns being on the distant ridge instead of the nearer one. He would range upon the right-hand gun (because the hollow is presumably shallower there); he would see that the subaltern of the ranging section got his line accurately; and he would require at least two verifying rounds distinctly observed "over" before going to time shrapnel. In a case like this, if ranging with the right section, it would not be amiss to send the left section subaltern out to the flank to observe, and so check the battery commander's observation.

Selection of Ranging Point.

When giving the line to the battery, it is not always desirable to give it the line to the target. It frequently occurs that the enemy has selected a position for (say) his guns in which they are not easy to range upon, because many of the shells fired at them will be lost to view. In such a case the B.C. should look out for a piece of easy ground near the target, within say 5 degrees either side of it, or for a slope beyond the target or short of it, and should endeavour to pitch his first shell into the centre of this area. Having got the line and approximate range, he then shifts the line on to the target.

The Kite.

When observation is difficult, it is sometimes advisable to fire a time shrapnel with short fuze at the first round, even when it is intended to range with percussion. This is commonly called a "kite." It is useless for finding the range, but enables the line to be corrected at once.

RANGING WITH TIME SHRAPNEL.

This is only applicable to equipments in which the setting of the fuze is always that due to the range, as modified by the *corrector* described below.

If, in Fig. 98, the corrector be lengthened till all the fuzes burst on a plane about 10 feet from the ground, then the lower edge of each cloud of smoke will either obscure the target or be obscured by it, thus enabling unders and overs to be distinguished even more readily than when the shell are burst on graze.

This can only be done with fuzes which burn regularly, since high bursts are useless for observation. Time-shrapnel ranging with a bad fuze would entail a great waste of time and ammunition.

An inherent defect of the system is that the appearance of the burst gives no clue to the actual distance over or short of the target, unless the strikes of the bullets or the body can be distinguished, since two bursts in air 500 and 50 yards short look much the same.

On the other hand, ranging with time shrapnel does away with all complications due to the nature of the ground at the target, such as the "ranging traps" already referred to. It is especially useful where the ground falls away steeply behind the target, rendering grazes over difficult to observe, and, which is most important, it gives a certain amount of effect on the target during the process of ranging.

It has been pointed out by General Rohne that when ranging with percussion the B.C. may not be able to see grazes short without going forward to observe, and getting shot; whereas when ranging with time shrapnel bursts over and bursts short are equally visible, being all on the same plane.

After several years' experience, ranging with time shrapnel has been adopted by the French artillery as their normal method; and in this the French have been imitated by several other nations which have lately re-armed with quick-firing guns. The Germans, like ourselves, have wisely avoided the adoption of either time or percussion ranging as the standard method, but use whichever is best suited to the case.

Crossed Bursts.

There is one peculiar method of time shrapnel ranging, which is frequently used in the French army.

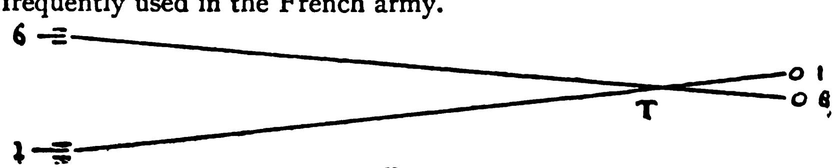


FIG. 96.

Suppose the two flank guns of a battery firing time shrapnel, each being accurately layed on the same point of the target, and let them be fired at 5 seconds interval. Then if the range be too long, the lines of fire will cross at the target, so that, if No. 1 gun be fired first, then the first cloud of smoke to appear will be on the left of the target, and the second, from No. 6 gun, on the right of the target. If the bursts are short of the target, No. 1 will appear on the right and No. 6 on the left, while if the bursts are directly over the target they should coincide.

The normal French method of ranging is to fire one round of battery fire at 3 seconds interval with the same elevation and fuze, followed by a second round of battery fire at an increased elevation and fuze. There are four guns in the battery.

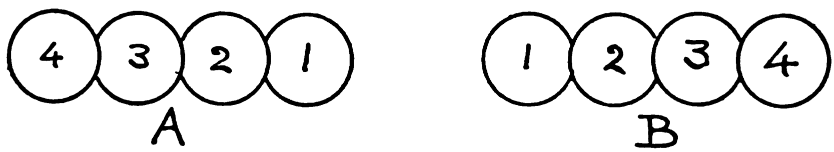


FIG. 97.

Then if the first four bursts are short, they appear in succession from the right, as at A; if the second four bursts are over they appear in succession from the left, as at B, and the target is bracketed.

The above method has been suggested for firing at balloons (Captain Aizier, in the Revue d' Artillerie.)

A variation of this method was tried by the French Artillery at Chalons in 1908. If, instead of keeping to one fuze, each round of battery fire is fixed with "corrector increase 2," then if the range is too short the line of bursts will slope downwards from right to left, if too long it will slope downwards from left to right.

This method was found to answer well for night firing. The wider the front of the battery, the easier it is to observe. A bracket of at least 400 yards is necessary.

FINDING THE FUZE.

Continental Methods.

In Continental field equipments each nature of gun has a special fuze, graduated in metres of range. When changing to time fuze, the fuze is simply set to the range, and corrected if necessary by a device called a "corrector" which alters the apparent reading of the sight without affecting the elevation given. A somewhat similar system has been adopted in England.

The German method is however different. The German corrector alters the elevation, not the fuze. Thus at 3000 metres, if the fuzes are bursting on graze, the B.C. orders "corrector 2 up." The socket of the back sight (see figure 28, page 85) is raised 2 divisions, so that when the gun is re-layed the trajectory is raised above the target, though the sight is still set at 3000. The fuzes, which are still set

at 3000 (or rather 30) will now burst in air, but beyond the target. To make them effective, the range, and with it the fuze, will have to shortened to 2900. This procedure appears to us most cumbrous; and it is rendered worse by the fact that one division of corrector corresponds to a different number of metres of range at each elevation, so that if more than 2 divisions of corrector are given (or 1 division for time H.E. shell) the range has to be verified afresh. The only advantage is that the fuze-setting number goes on setting to whatever range is ordered, and has not to concern himself about the corrector.

English Method.

The range indicator upon which the elevation gives to the gun is shown has an inner ring, called the fuze indicator, upon which the length of fuze for each range is marked. The inner ring can be shifted with respect to the outer so as to alter the reading of the fuze ... by which the inner ring is shifted is ... that the normal

Page 239.—The present fuze scale, with proportionate corrector giving a correction applicable to all ranges, cannot be attached to the range indicator on the gun. The yard scale on the fuze indicator is proportional to the logarithm of the time of flight to each distance, and has no reference to the angle of elevation. Fuze indicators are carried on the gun limber and on the wagon body.

When once the setting ... of fuze for any given range has been determined, then, so long ... atmospheric conditions remain the same, the same setting will give the correct length for any other range.

The Fuze Echelon.

After detailing the ranging section, the Battery Commander orders the remaining 4 guns to set their corrector scales at lengths increasing by ten divisions, giving 4 fuzes of different lengths. When the 100 yards bracket has been found, these 4 fuzes are set and the guns are fired, usually at the lower elevation of the bracket. From these four fuzes the B.C. selects the most suitable, thus obtaining the corrector setting for the whole battery.

In changing on to a fresh target at direct fire there is no necessity to fire a fresh fuze-echelon, since the corrector setting holds good for ...

Page 239.—The fuze echelon is now fired at the mean of the 100 yards bracket. See note to page 237.

Principles of Fuzing.

Whatever be the special method adopted, certain fundamental principles of fuzing must be borne in mind. The chief of these is that, unless the bullet-strikes are visible, it is never safe to accept a fuze as correct without "going forward for a graze." If the fuzes are all bursting in air, it may mean that the range is short and that the shell are bursting hundreds of yards short of the target, where they are quite ineffective. By lengthening the fuze till a couple of grazes are obtained, any error in range will be detected, and the fuze may then be shortened again till it gives only 10 per cent. of grazes. It is not necessary to increase the fuze for the whole battery, as this would make the fire temporarily ineffective. The ranging section, or even a single ranging gun, is sufficient to verify the fuze.

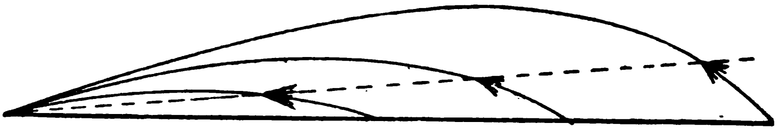


FIG. 98.

Typical Height of Burst.

The next principle is, that provided the range has been correctly found the height of a shell burst at the proper distance from the target corresponds to a given angle above the line of sight, equal to about $\frac{3}{1000}$ or 11 minutes of elevation. The approximate truth of this may be proved mathematically, but it is sufficiently evident on inspecting Fig. 98. Thus, at a range of 5000 yards the slope of decent of the 18 pr. is 1 in 3, so that a shrapnel bursting 50 yards short would be 50 feet high. The height given by the $\frac{3}{1000}$ rule is 45 feet, corresponding to a burst 45 yards short of the target. Similarly at 3000 yards the height by rule is 9 yards, which, with an angle of descent of 1 in 8, gives a burst 72 yards short of the target.

In the French telescope a horizontal line across the field marks the $\frac{3}{1000}$ angle, so that it can be seen at once whether the shrapnel are bursting correctly; if not, they are regulated by the "corrector." In our equipment the height of burst may be observed by elevating

Page 240.—With the 18 pr., a height of burst of 10 minutes is found to give the best results. About 30 minutes is suitable for a field howitzer.

It is sometimes supposed that it is correct to burst shrapnel extra short when the target is thin and wide, as a line of extended infantry. This, however, is hardly borne out by arithmetic. Suppose a line of skirmishers advancing at 3000 yards, the vulnerable surface of each man being 1½ yards high and ½ yard wide, or .75 yard, which is a liberal estimate. Then the most economical effect will be produced if the dispersion of the bullets is such as to allow one bullet to each man. The "typical height of burst," 72 yards short, gives 1.35 bullets to each man; to get 1 bullet per man the shell should burst 84.75 yards short. For a line of men kneeling, each presenting .375 yards of front, the shell should burst 58.8 yards short. At shallow targets, it is only when firing at men erect and fully exposed that the best distance of burst exceeds that corresponding to a height of $\frac{3}{1000}$ of the range, and such instances are of rare occurrence.

Deep Targets.

A target which frequently occurs on service is a space of ground, say 400 yards deep, irregularly covered with advancing infantry. Independently of searching for depth by varying the elevation, it is necessary to sweep the ground with bullets as thoroughly as possible. In order to do this we must burst the shrapnel high enough to keep the bullets—or some of the bullets—off the ground till their effective velocity is expended. This will be better understood on referring back to the two illustrations of the shrapnel cone. Fig. 82, representing the burst of the 15 pr. B.L. shrapnel at 3000 yards, may be taken

roughly to represent also the burst of Q.F. shrapnel at 4000 yards. When burst at a height of $\frac{3}{1000}$ as at S_1, we do do not get the full advantage of the depth of the cone; the maximum depth of ground swept is obtained by shortening the fuze till the burst is 65 feet high, as at S_3, after which the depth falls off again.

In Fig. 83, representing the burst of a modern high-velocity shrapnel at 3000 yards, we see that, thanks to the flatness of the trajectory, the "hauteur type" of $\frac{3}{1000}$ is sufficient to give full effect to the depth of the bullet-cone. In this case nothing is gained in depth by shortening the fuze to raise the point of burst, and when raised to 100 feet, which corresponds to 330 yards short, the bullets lose their effective velocity before reaching the target.

Raising the Point of Burst.

It is also possible to gain increased depth of effect by raising the point of burst without shortening the fuze—in other words, by giving increased elevation. Thus in Fig. 83, after having found the fuze for the $\frac{3}{1000}$ height of burst, the trajectory might be raised 30 feet or 12 minutes, causing $\frac{3}{4}$ of the bullets to fall over the target and $\frac{1}{4}$ short. This expedient is a dangerous one and should not be adopted unless the strikes of the bullets can be observed. Moreover the increased effect can only be obtained at the expense of the effect on the front line of skirmishers fired at, which effect is a maximum when the trajectory (or rather the axis of the bullet-cone) passes through the target.

Shielded Guns.

The object is to sweep the ground behind and around the guns with bullets, so as to prevent any movement in the battery, and at the same time to get as many direct hits as possible. The range and line for each gun must be carefully corrected and the fuze lengthened till about 75 per cent. of shell burst on impact. It must be remembered that a percussion shrapnel which bursts as it passes through a gun-shield will appear to be over.

If the observing conditions are such as to prevent precise gun-for-gun shooting, then little effect is to be expected from direct shrapnel fire. Recourse must then be had to oblique or cross fire, or to howitzer shrapnel fire.

The best tactical method of attacking shielded guns is by the concentration of the fire of dispersed batteries. For though a shielded gun may withstand frontal fire for a long time, the detachment will stand a poor chance when the shells begin to come in from three directions at once. Another method which may be adopted by the stronger party is to push forward single sections to within close range, in the hope of knocking out the enemy's guns by direct hits, while the remainder of the artillery covers the advance of these sections and keeps the enemy fully employed.

The Distance of Burst.

The correct distance of burst is directly proportional to the density of the bullet-cone and to the vulnerable surface exposed by each man of the enemy.

Page 241, last para.—Mathematically, the density varies inversely as the square of the distance of burst.

This is shown as follows:—

Take a typical shrapnel, giving at 3000 yards a bullet-cone containing 300 bullets, with an angle of opening of 1 in 5. The "hauteur type" of $\frac{3}{1000}$ of the range gives a burst 72 yards short; then the cross-section of the cone, at 72 yards from the burst, will be 14.5 yards in diameter, with an area of 165 square yards, and a "density" of 1.8 bullet per square yard.

Let this shrapnel be burst 72 yards short of a line of skirmishers (interval immaterial) of which each man presents a vulnerable surface $1\frac{1}{2}$ yards high by $\frac{1}{2}$ yard wide, or .75 square yard. (This, as will be seen, is a liberal estimate.) Then if the shrapnel gives a good pattern—that is, if the bullets are uniformly distributed over the cross-section of the cone—each skirmisher will be hit by $1.8 \times .75$ or 1.35 bullets on the average, which is a waste of 35 per cent. of bullets. Supposing the skirmishers closed to one man per yard, then 14.5 skirmishers will be hit by 20 bullets.

Now let the shell be burst 84.75 yards short instead of 72 yards; then the cross-section of the cone will be 225 square yards, with a density of 1 bullet to .75 yard. The diameter of the cone will be 17 yards nearly, providing one bullet apiece for 17 men, instead of 1.35 bullets apiece for 14.5 men as before.

Page 242.—This calculation assumes that the distribution of the bullets is uniform, which of course is never the case. If the distribution is haphazard, then it may be proved mathematically that the probable number of men killed will be greatest when the distance of burst is such as to give an average of 1.24 bullets to each man. The minimum distance of burst is limited by the number of shrapnel wasted by bursting on graze, owing to the error of the fuze.

FIG. 99.

Maximum Effect.

The above is the maximum theoretical result which can be obtained by suiting the point of burst to the given conditions, which require a density of 1 bullet to .75 square yard. It will be observed that this maximum result is nothing like 35 per cent. better than the 72 yards result, in which 35 per cent. of bullets were wasted by putting more than one bullet into each man. The reason for this is shown by Fig. 99. In the left-hand figure, representing the cross-section of the cone at 72 yards. we have a band $1\frac{1}{2}$ yards high extending across a circle 14.5 yards in diameter, and occupying 0.13 of the area of the circle; in the second figure we have a band of the same height, across a circle 17 yards in diameter, occupping only 0.1 of the area. In the second instance we therefore utilize a less number of the bullets contained in the shrapnel, namely, 17 as against 20, although we apply them more economically.

When firing at a target of no depth, such as a single line of infantry, the proportion of effective bullets falls off rapidly as the distance of burst required to produce the required density is exceeded. It is therefore usually advisable to burst the shrapnel too close to the target rather than too far from it.

Area of Targets.

The following figures are given by Gen. Langlois as representing the vulnerable area of a soldier, not including his clothing or equipment:—

Infantry soldier, standing, front view ...	0.57 square yard.
,, ,, ,, side view ..	0.33 ,, ,,
,, ,, kneeling, front view ...	0.38 ,, ,,
,, ,, lying down, front view	0.19 ,, ,,
Horse, front view	1.0 ,, ,,
,, side view	1.90 ,, ,,
Cavalry soldier, front view	1.35 ,, ,,
,, ,, side view	2.16 ,, ,,

Practical Rules for Fuzing.

We may now enunciate some simple practical rules for fuzing:—

1. Start the fuze-echelon at a corrector setting at least 200 yards short of the fuze laid down for the range. No effect, and no information as to the proper length of fuze, is obtainable from an echelon of fuzes all bursting on graze.

2. Open section fire with the last fuze of the echelon which bursts in air.

Page 243, 3rd para.—The corrector is now graduated to give the effective fuze. With our present fuze, 10% of grazes corresponds to an average height of burst of 10 minutes.

4. At a deep target set the fuze to burst 50 yards shorter than the normal setting as above determined.

5. At shielded guns lengthen the fuze till it gives 75 per cent. of bursts on graze.

6. At a scattered target such as an extended line of skirmishers, do not attempt to cover an in increased front by shortening the fuze, but burst your shell at the most effective distance—namely, close up—and obtain increased lateral spread by sweeping combined with increased rate of fire.

7. At scattered targets and at shielded guns only a small proportion of men hit per shell can be expected. Therefore do not hesitate to use the full power of the Q.F. gun, and put in a number of shell sufficient to secure the desired result.

Velocity of Sound.

It may be occasionally useful to know that the report of a gun travels at about 400 yards per second. If it be possible to observe the number of seconds between the flash and report of an enemy's gun, this number multiplied by 4 will give the range in hundreds of yards.

Similarly, if another battery be firing at the enemy's infantry, the time between the report of the gun and the visible burst of the shrapnel will give the fuze the battery is using, and the time between the smoke and report of the shrapnel will give the distance.

The above rule rather over-estimates the range.

If a pendulum 11.41 inches long be hung from the director tripod, then each single oscillation counted between flash and report will correspond to 200 yards of range. Similarly, a pendulum 2.85 inches long will beat once for every 100 yards of range. The length of the pendulum is measured from the point of support to the centre of gravity of the pendulum.

As might be expected, the velocity of sound is considerably modified by wind, and the above methods are only to be trusted on a moderately still day.

Wide Targets.

When the target is considerably wider than the battery, special methods of ranging may have to be employed. At a wide target parallel to the front of the battery, and on the same level throughout, it will suffice to range with parallel lines of fire on the central portion, and then to open out the lines of fire and sweep as laid down in F.A.T.

Thus if the target be 300 yards wide, it is divided into 3 portions each 100 yards wide; each section is directed on the centre of the opposite portion, and sweeps so as to cover a front of 100 yards. Theoretically the lines of fire of the two guns of each section should be inclined outwards before sweeping is ordered. If this be done, then the outward deflection and sweep are given by the section commander's sweeping rule:*

"Multiply the front of the target in degrees by ten, and give this amount of deflection and sweep in minutes to each gun."

Thus for a target of 3 degrees front, at any range, the order to a section would be:

"No. 1, 30 minutes more right deflection."
"No. 2, 30 minutes more left deflection."
"Sweep ½ degree right and left."

Where the target is both oblique and on a lateral slope, ranging on the centre and giving outward corrections is unsatisfactory. The best method is to range with the right and left sections on the ends of the target, and halve the difference for the centre.

Searching.

This is equivalent to distribution in depth. There are two methods, both laid down in F.A.T.; the ordinary method consists of giving successive alterations of elevation to the whole battery; the other method, known as section searching, is to give each section a different elevation and let each sweep so as to cover the whole front of the target. The latter method has the advantage of bringing the whole

* I am indebted for this rule to Major C. Battiscombe, R.F.A.

area under fire simultaneously. Also the laying and fuze-setting are likely to be mote regular, since each section maintains the same elevation and corrector setting, whereas with the first method, unless the target is on level ground, either the angle of sight or the corrector setting has to be altered at each round of battery fire.

Registered Areas.

It will often be advisable to expend a few rounds in ranging on points at which the enemy may be expected to appear, or on important defiles such as bridges. This is regularly carried out in the French Artillery. See Chapter XXVIII.

CHAPTER XXVII.

FIELD HOWITZER FIRE.

General Principles.

The object of the existence of a field howitzer is to engage a standing target such that field guns cannot reach it. The target may be a position held by troops keeping under cover, or by troops entrenched, or by troops in field-works with overhead cover. Or the target may be shielded artillery, with detachments protected against direct shrapnel fire. In none of these cases is any advantage to be gained by coming into action in the open, and we may therefore safely say that the normal method of opening fire for howitzers is from a covered position.

~~In exceptional cases field howitzers may be called upon to act as~~ ~~... repel an~~ attack by direct fire, to engage moving tar- ~~... at close quarters.~~ All

Page 246.—All Q.F. field howitzers are now expected to act as guns when no special howitzer target presents itself. To facilitate this, modern howitzer sights are graduated in metres of range for each charge, so that the fire discipline is the same as with a field gun. With the German Q.F. field howitzer, ranging is normally carried out with time fuze, full charge, even when the subsequent fire for effect is to be at high angles.

As has ... cover from fire to a field gun, since ... enemy's shell is greater than the angle of elevation of our own. But this does not apply to howitzers. A howitzer with an angle of elevation of 45° can fire from behind a "covering mass" so steep that the enemy's bullets which clear the crest pass harmlessly overhead. Such covering parapets are rarely to be found in nature. But a row of houses, a high wall, or a railway embankment may sometimes be found, affording perfect protection against anything but high-angle fire

From a gunnery point of view, therefore, the object of the howitzer battery should be to get as close as possible behind steep cover.

Such a position has the further advantage that the battery is close up to the observing position on the crest from which its fire is regulated.

The Occupation of a Position.

The gunnery points involved have already been considered in Chapter XXIII. In the case of howitzers additional stress must be laid upon one point, namely, the necessity of having the wagons alongside of the guns. A howitzer shell weighing 35 to 40 lbs. is not a handy load for a man to double 20 yards with. Moreover, when firing from a covered position the shallower the target the less becomes the likelihood of the enemy's shell finding it.

Page 246.—A howitzer firing full charge requires about 20 feet of cover above the muzzle to conceal the flash.

Attention has already been drawn to the importance of sound platforms, and care exercised in this respect will be found to expedite the opening of effective fire.

In other respects it is much easier to find positions for howitzers than for guns; they have no danger angle, no dead ground in front of them, and no trouble in clearing the crest.

Ranging.

Howitzer shell are too valuable to be lightly thrown away, and rounds should therefore be economised in ranging. Thus when a long bracket is formed at 3000—3400 of say one shot 100 short and one 300 over, the next two rounds should not be 3100—3300 as with a field gun, but 3050—3150, probably saving two rounds at the expense of a little extra calculation. Such economy is the more necessary that the range must be determined with more accuracy than is required for a field gun, since the shrapnel bullets, owing to their low velocity and sharp angle of descent, only search a small area of ground.

Time shrapnel ranging is rarely employed with a howitzer. Owing to the comparatively long time of flight and to the steep angle of descent, the vertical dispersion of the fuzes is much greater than with a gun, and it is not easy to get good bursts for observation. Moreover the large howitzer shell, when burst on graze, are much easier to observe than gun shell.

Selection of Charge.

As already explained in the Chapter on Ammunition, a Q.F. howitzer has usually 6 different charges. The smallest charge that will carry the shell to the target is selected, in order to obtain the steepest angle of descent. An exception is when the howitzer is employed for direct demolition, as when firing lyddite shell at a building. In such cases the full charge is used, partly on account of the greater accuracy obtained. This is because the time of flight is shorter, and the shell is exposed for a shorter period to the wind.

Height of Burst.

A howitzer shrapnel requires to be burst at a greater height than a gun shrapnel. The maximum effective height is that at which the bullets have still a striking energy of 60 foot-pounds on impact; the best height, within this limit, is that which gives a bullet-cone which provides one bullet per man of the enemy.

The maximum effective height for any howitzer and for any angle of descent may be readily worked out by the ballistic table. (See page 21, and example, page 27.) For instance, the maximum effective height for the 5" B.L. howitzer at 4000 yards is about 330 feet. But the best height of burst is considerably less. Taking the area of a man, measured at right angles to the trajectory, as ½ square yard, the distribution should be such as to give 2 bullets per square yard. There are 623 bullets, and the angle of opening is 1 in 3; therefore the cross section of the cone at the target should be 312 square yards, which makes its diameter 20 yards, and the height of the cone (that is, the distance from base to apex) 60 yards, which, with an angle of descent of 30 degrees, corresponds to a burst 90 feet high.

Howitzer Craters.

There is one special application of field howitzer fire which merits notice. A lyddite shell bursting in stiff soil such as clay makes a crater some 3 feet deep, which serves as an efficient rifle pit. Thus the Japanese were assisted in their attacks on the Port Arthur forts by the shelter afforded by the craters made in the glacis by their own howitzers.

Observation and Correction of Fire.

When a field work has to be searched with shrapnel, or a field casemate breached with H.E. shell, accurate observation and correction of fire is required, otherwise the expenditure ot time and ammunition will be very great.

Although this is really siege work, a field howitzer battery must be able to undertake this nature of fire when necessary.

Siege Method.

This consists in observing the fall of each shot with two telescopes placed at least 500 yards apart and connected with the battery by telephone. Each telescope has a *graticule* or series of lines ruled in the field, each line corresponding to say one minute of angle.* Suppose each telescope directed at the point to be struck ; then a round is observed say 8 min. R. in the right telescope and 3 min L. in the other. These observations are telephoned to the battery, where the B.C., by means of a scale of natural tangents for the range, plots the fall of the shot on a piece of paper ruled in squares, and finds it say 63 yards over and 12 yards right.

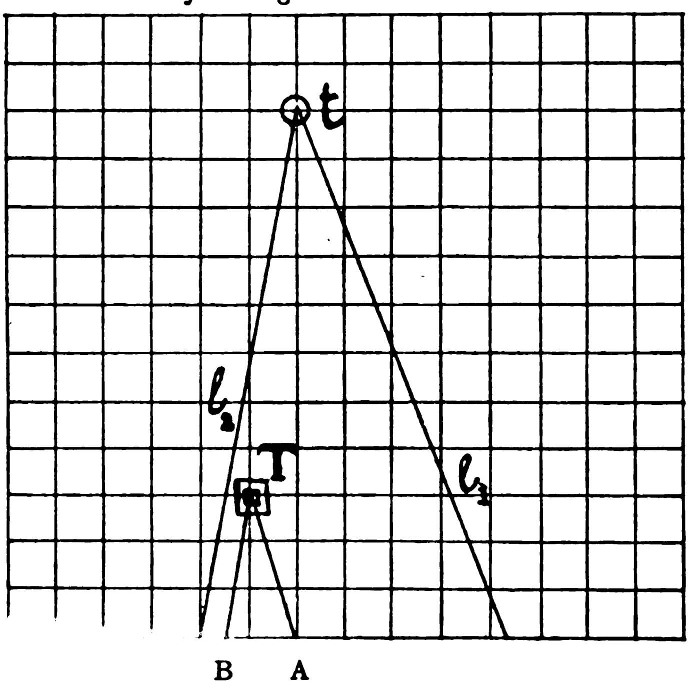


FIG. 100.

* The new director is sufficiently accurate to replace the graticule telescope for this purpose.

Fig. 100 shows a chart of this kind. The range is 3600 yards, so that the natural tangent of 1 minute is 1 yard. Let T be the target, A and B the two observing stations. Then the plotting officer draws line l_1 parallel to TA and 8 yards (to scale) from it; he draws line l_2 parallel to TB and 3 yards from it, and find the lines intersect at t. Then by measurement t is 63 yards over and 12 yards to the right of T, and the next round is corrected accordingly.

This method is only adopted for deliberate work. Once the observing stations established and plotting chart made out it is remarkably quick. But the practical delay is in measuring the distance between the observing stations, solving the triangle, and setting off the angle ATB on the chart.

When the siege method is not practicable, the method of "combined observation" laid down in F.A.T. must be used.

In fire of this nature, which is practically siege work, the elevation for each gun and for each round is corrected by the mean range found by that gun (see Chapter XXX) as determined by the three last rounds fired from it. Thus the correction keeps pace with the influences affecting the flight of the shell, such as rising wind or falling temperature.

CHAPTER XXVIII.

THE FRENCH SYSTEM OF FIRE-DISCIPLINE.

NOTE.—Officers are recommended to study General Rohne's pamphlet on this subject. A copy of the English translation by Lieut.-Col. Crowe, R.F.A., was issued officially in 1903 to Artillery Brigades.

Following the introduction of the 1898 Q.F. field equipment, the French Artillery have adopted a novel system of fire-discipline intended to utilise the power of the new gun in the fullest possible manner. This system has now been adopted, in principle, by most of the nations which have re-armed with Q.F. guns, and it has exerted a marked influence even upon the regulations of those Powers which have not adopted it, such as Germany, Russia, Austria and England. It merits careful study by all officers of the Horse and Field.

The French Equipment.

The details of this are given in Part IV. The French battery consists of 4 guns and 12 wagons. Each gun in action has an armoured wagon body unlimbered and up-ended alongside of it; two other wagon bodies are also brought up, behind one of which, on a flank, the battery commander takes shelter.

The gun is a shielded Q.F. gun with steady carriage; it has a high velocity and flat trajectory. The ammunition consists of shrapnel with a proportion of H.E. shell; the fuze is set to the gun range by a machine on the wagon, and corrected if necessary by an adjustable scale on the machine.

Fire Discipline.

The main principles of the French system are as follows: Great importance is attached to opening *effective* fire on the enemy in the shortest possible time after coming into action, in order to render his return fire ineffective. With this object in view, the range is normally found with time shrapnel, and at soon as a long bracket has been obtained it is searched from end to end by the rapid fire of all the guns, each gun increasing the elevation and fuze after every two rounds.

When the target is a wide one, each gun *sweeps* or distributes laterally as well as searching. In the first case each gun fires two rounds at each of 4 elevations; in the second, 3 rounds at each. After this opening burst of fire the range and fuze are corrected and accurate fire proceeded with until the target is completely destroyed.

Rafales.

A "rafale" or storm of fire consists of several rounds of rapid fire

Page 250.—In ordinary cases, the French no longer fire a *rafale* of *tir progressif* as soon as the long bracket is found. The present egulations restrict this method to fleeting targets. The bracket is duced to 200 metres, or 100 metres if possible, and searched by ccessive salvoes.

have been found the battery proceeds to slow fire (during which fuzes are prepared) alternated with *rafales* timed to take advantage of any movement of the enemy or to check any signs of recovery on his part.

Preparation for Opening Fire.

This is not to be confounded with preparation for action. The battery usually comes into action under cover (the forward covered position being preferred) and the line is obtained with the battery telescope and dial sights. Even when the battery comes into action in view of the target, laying is preferably by aiming-point for line and by clinometer for elevation. The target is allotted to each gun, and the "corrector" of the fuze-punching machine set so as to give

Page 251.—The French artillery have now been equipped with telephones, and the fully-covered position is coming more into fashion.

Ranging.

Two elevations differing by 400 metres, or less at short ranges, are ordered, and a "salvo" (corresponding to the English "one round battery fire 3 seconds") is fired at each elevation.

The French regulations lay down that if only one burst out of each salvo can be observed, and if the results concur, the bracket may be accepted. If time permits, the bracket is subdivided by another salvo, giving a bracket of 200 metres.

Tir Progressif.

Starting with an elevation 100 metres less than the lower elevation of the 200 metres bracket, the B.C. orders "tir progressif." Each gun then fires two rounds of time shrapnel, fuzed to burst at a height of $\frac{3}{1000}$ of the range, at that elevation, followed by two more at an elevation and fuze increased by 100 metres, and so on till each gun has fired 8 rounds in quick succession. Thus if the bracket be 3400—3600, the successive elevations will be 3300, 3400, 3500, and 3600. The B.C. may if he chooses order intervals of 50 metres instead of 100 between the different elevations. It is stated that the 32 rounds of "tir progressif" can be fired in one minute, without setting fuzes beforehand.

Tir Fauchant.

The normal width covered by the fire of a 4-gun battery is 100 metres; if it is desired to double this width, then at the order "Fauchez" (sweep) each gun, after the first round, gives successively 3 turns of the traversing wheel left, 3 more turns left, back again to centre, 3 turns right, 3 more right, back again to centre, and so on. This procedure enables a single gun to cover a target 50 metres wide at 2500 metres.

Tir Progressif et Fauchant.

Each gun fires 3 rounds at each of four different elevations. The first three rounds are: centre, three turns left, three more left; the next are centre, three right, three more right; and so on, making 12 rounds per gun. It is stated that the 48 rounds can be fired in 1½ minutes, without setting fuzes beforehand.

Echelonnement.

To distribute the fire over a target each gun requires to be layed at a different angle on the aiming-point. The increment for each gun is calculated by the B.C. Suppose he makes it 5 (thousandths) for each gun; then he gives the direction to the flank gun, and orders "*échelonnez de 5*," when each gun gives 5 thousandths more deflection than the last. Thus if the deflection for the right gun is 80 on the base-plate, then No. 2 gun gives 85, No. 3 90, and No. 4 95.

Change of Target.

Since the layers do not aim at the target but at a conspicuous aiming-point, and since elevation is given by clinometer, it is unnecessary to point out the new target to them. The B.C. measures the angle from the aiming-point to the new target, and simply orders a fresh direction and a fresh clinometer elevation.

Fire at Moving Targets.

In the case of a small rapidly-moving target it may be necessary to lay direct on it. But the normal procedure is to search the ground over which the target is advancing with "*tir progressif.*"

Deliberate Methods.

When immediate effect upon the target is not required, and when accurate ranging is of consequence, the older methods are followed. The target is bracketed and the bracket subdivided to 50 metres and checked by verifying salvoes. Either percussion shrapnel or, preferably, time shrapnel with fuzes set to burst close to the ground is used. Of the two, time shrapnel is considered the more easy to observe.

Registered Areas.

During any pauses in the action, ranging rounds are fired at spaces of ground on which troops may appear, and the direction, elevation, and fuze for such areas are recorded or "registered." On the large scale, batteries (*batteries de surveillance*) or even brigades are told off to watch suspected areas, ready to search the ground with *rafales* should an enemy appear. Such batteries are usually kept ready in action in the "forward covered" position, just behind the crest line or other cover from view.

Close Support of Infantry.

Single batteries (*batteries de combat*) are sent forward to short range in support of the infantry. Sometimes *batteries d' accompagnement* are handed over to infantry brigades for a similar purpose.

MERITS AND DEMERITS OF THE FRENCH SYSTEM.

The leading idea of the French system is to throw all the head-work on the highly-trained battery commander, and to give the gunner nothing to do but to obey simple orders. The apparently complicated "tir progressif et fauchant" is not an exception to this rule, as the gunner's procedure is purely mechanical, requiring no reasoning, and

even if he makes a few mistakes it is of no great consequence. And this system is carried out so thoroughly that even when the target is visible the gunner is not allowed to lay on it, but has to lay on an auxiliary mark at an angle ordered by the battery commander.

This method is not without good points, especially in view of the excitability of the French gunner and the shortness of his service with the colours. But, in war, emergencies must arise on which the gunner has to think and act for himself. And if he is converted into a mere machine he will be helpless when no longer animated by the the directing intelligence of his officer.

Duties of the Battery Commander.

The captain commanding a French battery, whether he comes into action in the open or under cover, has to go through the same process of geometrical calculation as is required of his English confrère before the latter can open fire from the covered position—a tactical method which we have ceased to look upon as the normal one.

But, as in our own service, most of the B.C.'s preliminary work can be done before the battery comes up, so that if he rides a mile ahead of his battery he has ten minutes to make his calculations.

The French captain's means of communicating with his battery, as regards both the equipment and the training of the battery communication staff, are far inferior to those existing in our own service.

The French battery commander has several points in his favour as compared with his English opposite number—

His battery of four guns is much easier to handle and control than a six-gun battery.

The flat trajectory of the French gun minimises the effect of errors in ranging.

Errors in clinometer laying are less frequent than those which occur with open sights; the latter are principally due to the layers failing to locate the target.

Duties of the Gunners.

The French gun-layer has to handle a complicated pedestal sight. But apart from this his duties are simpler than those of the English gunner, and afford less scope for making mistakes. The French gun is less handy than our own, and the process of *abatage* is an awkward one. On the other, fuze-setting is rendered easier by the use of the machine.

French Method of Opening Fire.

A series of *tir progressif et fauchant* consists of 48 shrapnel, each containing say 260 effective bullets out of 300. The effective depth of the bullet-cone being 300 metres, these 12,480 bullets are distributed over a space 600 metres long by 200 wide, the bullets being thickest in the centre of this area. This gives .104 bullets per square metre of ground. The angle of descent of the shell being 1 in 10, or nearly 6 degrees, then the mean angle of descent of the bullets will be about 8 degrees or 1 in 7½ (vide illustration of French shrapnel

cone). Therefore the number of hits on a vertical surface 1 metre square will be 7.25 × .104 or 0.75. Taking the average surface of a man alternately lying and advancing at ¼ square metre, this gives .188 bullets per man or about 1 bullet to 5 men. That is, of any troops, not under cover, in the area covered by the *tir progressif* one man in 5, or 19 per cent., will be hit. If there are any horses in the area, then 75 per cent. of the horses will be hit. This is on the assumption that the bullets are evenly distributed, and that none are wasted by putting two bullets into one man. But even at the lowest estimate the probable percentage of hits represents a crushing effect upon any troops other than shielded artillery within the fire-swept area. And if the artillery be caught coming into action, or limbering up, the effect will certainly be to put the battery out of action for some time.

Conclusion.

To a gunner accustomed to other methods, unbiassed criticism of the French system is exceedingly difficult. It is believed however that the following conclusions will be accepted as safe by most officers of the Horse and Field :—

1. Good or bad, the French special methods do not preclude the use of the older and slower systems of ranging. They invest the Battery Commander with additional powers, to be used or not as he thinks fit. Therefore the French ranging methods should be embodied in all systems of fire discipline.

2. *Tir progressif* and *tir fauchant*, Anglicé searching and sweeping, are reduced to a mechanical drill requiring no thinking on the part of the gunners, so that the B.C. can apply either or both combined by a single word of command. This has now been done in our own service.

3. Most English officers will agree that direct laying, especially when assisted by a telescope, is preferable to clinometer and aiming-point for the support—especially the close support—of the infantry attack.

4. Finally, there can be no doubt that the practice of registering the range and fuze of all probable targets is thoroughly sound. And it may be added that it will frequently be desirable to detail one gun of the battery to carry this out, even while engaging another target, provided the proper tactical rate of fire can be kept up with the remainder of the battery.

CHAPTER XXIX.

VISIBILITY.

(Officers are recommended to study General Baden-Powell's book on "Scouting.")

The keynote of a landscape is confusion of detail. All natural objects are irregular in shape and complex in outline. Any symmetrical object, such as a gun-carriage, tends to catch the eye at once. In Nature there are no straight lines (except the surface of water,) no circles, and no squares.

Again, there are no sharp contrasts in nature; the colour and tone of all natural objects are infinitely varied. For this reason any object of uniform colour, such as the side of a house or the flat surface of a gun-shield, attracts attention immediately.

Lastly, natural objects do not move about. So long as a man or a horse keeps still he often escapes notice. The hunter who sits for hours waiting for a shot knows this well; he also knows that the erect figure of a man is unlike anything in nature, and carefully avoids the upright position. It was a standing order in Natal that when men were seen erect on the sky-line the troops were on no account to fire on them, as they could not possibly be Boers.

The most conspicuous feature of a landscape is invariably the sky-line. Not only does any movement or any artificial-looking object catch the eye at once, but the sky-line forms the natural point of aim for all infantry. Accordingly it is especially important for guns to avoid it, since artillery in action are more stationary than any other troops, and have to remain longer under fire.

Not only symmetry of form but symmetry of order or arrangement makes for visibility. A single gun might escape notice, but six guns at regular intervals, though individually barely visible, form a group unlike anything in Nature, and arouse suspicion accordingly.

Time of Exposure.

It takes a certain period of time for a visible but inconspicuous object to catch the eye of observers. It is therefore sound to reduce the period of exposure to a minimum, even at the expense of additional momentary visibility. Thus, if it be necessary to cross a ridge in view of the enemy, the best way is to form line under cover and let every carriage cross as nearly as possible simultaneously. If the opposite plan be adopted, and it be attempted to steal over in column of route, then the first battery may possibly get over before the enemy realises what is happening, but the batteries following are likely to suffer severely.

In pushing forward guns in close support of the infantry, it would be foolish to trot a section across the open within 1500 yards of a

position, with every gun and rifle ready to open on it. But when the defenders are busy repelling an assault, their attention will be fully engaged at close quarters. It takes time to perceive a more distant object, and more time to get the men on to it and to open fire; and a section exposed for 2 minutes while trotting across 600 yards of open ground will have an excellent chance of getting through unscathed.

Application of Principles.

We will now consider the application of the above principles to service conditions. Take first the peace-time preparations. We have already, in the English pattern khaki uniform, an admirably inconspicuous dress. Most of the flashing metal work which we used to display has disappeared with the old pattern harness. The colour of our guns and carriages still however leaves much to be desired, being too dark and too uniform in tint. (I refer to the "Service Dress" tint, which is practically the same as the old lead colour.) It must be recognised that guns are meant for war and not for peace, and they must be mottled, clouded, or chequered, even at the expense of smartness of appearance on a ceremonial parade. Further, the under sides of guns and carriages, being in shadow and therefore darker than the rest of them, form the most visible features of the equipment; to compensate for this all under surfaces should be shaded off to a lighter tint.*

The flat front of a gun-shield forms a reflecting surface which no amount of paint can hide. The only resource left is to break the surface by hanging gun-buckets, drag-ropes, and miscellaneous stores upon it.

In other respects the gun-shield does not on the whole add to the visibility of the gun. We all know the distinctive appearance of a gun on a sky-line, with a wheel sticking up on each side and the muzzle in the middle.

FIG. 101.

When the space between the top of the wheels is filled up by the shield, it tends to reduce rather than to increase the conspicuousness of the gun, especially if the top of the shield is humped or curved. Moreover, the shield hides any movement of the detachment, which movement often enables the gun to be located.

Visibility of the Wagon.

There is unfortunately no doubt that a wagon placed alongside the gun is more visible than a wagon down the slope behind it. This position of the wagon is however necessitated by modern conditions,

* NOTE.—"Animals are usually dark above and light beneath, because this arrangement is exactly the opposite of what happens when light falls upon a solid body which need not be concealed. A normally-coloured animal in its normal surroundings will therefore not seem to be solid and will be practically indistinguishable at a short distance against a background of colour and of pattern similar to its own."

—Theodore A. Cook.

and must be accepted in spite of its disadvantages. On the other hand, it has been shown in the chapter on "Accuracy of Fire" that the wagon is less likely to be struck when placed alongside the gun than when behind it. (See page 38.)

But the real reason why the wagon must be placed alongside the gun is that under fire from a Q.F. battery the casualties among the numbers supplying ammunition, if they had to come out from behind their shields to bring ammunition up to the gun, would be so heavy as to stop the fire of the battery.

Smokeless Powder.

Modern nitro-powder gives very little smoke. But the broad white flash from the muzzle is conspicuously visible, especially against a dark background, which should accordingly be avoided when practicable. It has been found by experiment in France and Germany that the flash is visible over a crest when the gun is not more than 3 metres, or 13 feet, below the crest. Field howitzers firing full charge require about 20 feet of cover. The only means of concealing the flash of the guns at direct fire is by placing them behind a screen, such as a row of thinly growing trees, which permits the layers to see through while hiding the flash from the enemy. It is however the exception to find such a natural feature available.

It has been proposed to fix a shield to the gun, about 2 feet in front of the muzzle, with a hole in it for the projectile to pass through. The impact of the gases on this shield would help to check the recoil, while the visible flash would be materially reduced. But the idea has not as yet assumed a practical form.

Dust.

Both when moving into position and when the guns are in action the dust thrown up often betrays the presence of the battery. On the defensive, when there is plenty of time for preparations, it is desirable to water the ground in front of the gun-muzzle.

Artificial Cover from View.

The provision of such cover can rarely be attempted except on the defensive. It may take the shape of a thin irregular screen of brushwood either in front of the guns or behind them. Bushing up a gun by sticking bushes in the wheels is difficult to do artistically and usually makes it more conspicuous than before.

CHAPTER XXX.

THE ANALYSIS OF PRACTICE REPORTS.

This should be systematically carried out after every day of practice, the results obtained being of great use in discovering defects of materiel and bad laying or fuze setting. The layers and fuze-setters will certainly do their work more carefully if they know that they will be brought to book for any errors they may make.

We will select for analysis a series fired at a shielded battery in the open, under somewhat difficult conditions of observation. The series chosen is by no means an ideal one, being marred by several mistakes on the part of the battery commander and others.

(See Extract from Practice Report.)

In the first place, the B.C., believing in his range-takers, began at a range more than 600 yards short of the real distance. He was fortunate not to lose rounds 1 and 2 altogether. Having observed them very short, he should have made a bolder bracket than 300 yards, to 4000 or even to 4500 yards, and so have saved time and ammunition, instead of uselessly repeating 3800 and 4100. Next, at round 7, he was unlucky in getting one round barely over, at the extreme limit of the "sheaf of fire," and made things worse by wrongly observing round 10, which he took to be over instead of short. Rounds 9 to 14 show the pernicious influence of badly-conducted battery gun-drill. It is so easy when firing without ammunition to assume that each shot falls at the spot intended, and is always correctly observed. Evidently the B.C., after round 7, jumped to the conclusion that he had got his bracket, and rounds 9 and 10 are merely a formality to satisfy his conscience.

It is not till round 13 and 14, the two last of the fuzing series, that the B.C. realises that his range is short. Instead of using the ranging section, he orders a fresh echelon of fuzes at 4300, hoping to get his two grazes and possibly to produce some effect on the target. This is all right as far as it goes, though he would have had time for two more rounds at 4300 from the ranging section while the fuzes were being set. The B.C.'s further procedure is sound; he opens section fire at 4250 with rather a long corrector, hoping to get some more grazes; he does get them, and corrects to 4225 and corrector 180, which is a fairly good elevation. As he was engaging shielded guns, the B.C. should have lengthened his corrector to give 75% of bursts on graze.

The next step is to analyze the figures of the practice report.

Take the first round, layed at 3500 and marked 700 yards short; if it had had 700 yards more elevation it would have reached the target; therefore, according to this, the correct range should be 4200 yards. Write down the corrected range for each shot that grazes, and we have the following list:—

ANALYSIS OF PRACTICE REPORT.

No. of Rounds.	No. of Gun.	Elevation.	Judged by Range Party.	Corrected Range.	Error.
1	2	3500	− 700	(4200)	+ 40
2	1	3800	− 500	(4300)	− 60
3	2	3800	− 400	4200	+ 40
4	1	4100	− 200	4300	− 60
5	2	4100	− 150	4250	− 10
6	1	4400	+ 100	4300	− 60
7	2	4200	+ 10	4190	+ 50
8	1	4300	+ 80	4220	+ 20
9	2	4100	− 120	4220	+ 20
10	1	4200	− 10	4220	+ 20
14	6	4100	− 300	(4400)	− 150
17	5	4300	+ 60	4240	− 30
18	6	4300	+ 30	4270	0
19	1	4250	+ 10	4240	0
22	6	4250	+ 100	(4150)	+ 90
23	3	4250	+ 10	4240	0
27	6	4250	− 130	(4355)	− 115

Mean range 4240 yards.

The 50% rectangle for the 18 pr. Q.F. gun at this range is 35 yards long; therefore the 100% rectangle, into which all well-layed rounds should fall, is 140 yards long. Any of the above rounds which cannot be fitted into this rectangle must be struck out as unreliable. We may discard Nos. 1 and 2 as being too short for the range party to judge accurately. Of the remainder all but Nos. 14, 22, and 27 will fit into the rectangle. Eliminating these, we have 12 rounds left. Take the mean of these by adding together and dividing by 12, and we have 4240 yards, showing that the B.C. finally found the true range within 15 yards.

This range of 4240 yards is styled ***the mean range as found by the guns.***

On comparing this with the corrected range it will at once be noticed that round 14 was badly layed. Further, we see that No. 6 gun was shooting differently from the others, the errors being − 160, ± 0, + 90, and − 115. This is very irregular shooting. The left section subaltern accordingly proceeds to test his guns before gun-park inspection the same evening. Both being carefully layed on a distant object, he applies the clinometer and finds that No. 6 gun is pointing 17 minutes higher than the other. This, on examination, is found to be due to the drum having slipped, and is soon set right. But this does not exonerate the White layer, who is very properly wheeled into line and told that he will be sent back to the wagon if he lays so badly again. He admits to a circle of friends in the Canteen afterwards that "he knew the old girl was throwing a bit high, and tried to keep her nose down!"

Next for the fuzes.

Taking the rounds fired at 4225, corrector 180, we have:—

Round.	No. of Gun.	Position of Burst.	Error.
25	2	− 40 A	+ 6
26	1	− 55 A	− 9
27	6	(−130 G)	?
28	3	− 45 A	+ 1
29	4	− 30 A	+16
30	5	− 60 A	−14
31	1	− 50 A	− 4
32	2	− 50 A	− 4
33	6	(+ 70 A)	(+ 116)
34	3	− 40 A	+ 6

Eliminating rounds 27 and 33 as irregular, we have 8 rounds left to go upon. The mean point of burst is 46 yards short, and the average error only 7½ yards, which shows that the fuze-setting was good, in spite of one badly-set fuze (again) at No. 6 gun. The last error is a very natural one: the No. 1 was puzzled by the queer shooting of his gun, and his anxiety infected the detachment, with the result that the fuze-setting number began to lose his head and the fire-discipline slackened. All the trouble would have been avoided if the Section Commander had tested his sights on the previous evening.

Part IV.

MODERN Q.F. EQUIPMENTS.

	U.S. America, 1902.	Argentine, 1908.	Austria, 1905.	Belgium, 1905.	Brazil, 1904.	Bulgaria, 1905.	Chili, 1910.
s	3	2·95	3·01	2·95	2·95	2·95	2·95
apnel, pounds	15	13·2	14·72	14·3	12·1	14.3	14·3
llets	252	295*	316+16	295	235	294	350
e pound	36·6	50*	50 & 35	42	42	45	50
. shell carried	U.	Yes.	Yes.	Yes.	Yes.	U.	U.
ty, f.s.	1700	1665	1640	1640	1600	1640	1675
y, foot tons	300	254	275	266	215	266	278
n, cwt.	7·1	6·5*	7	6·67	5·7	7·52	6·9
n and carriage, cwt.	22·3	18	20	20	16·3	20·25	20·2
n and limber filled, cwt.	36·6	31·5	37·5	34.5	26·7	34.5	33·5
mpressed air	S.	S.	S.	S.	S.	S.	S
evation, degrees	16	15*	18	15	17	15	17
h way, degrees	4	3	4	3½	3	3	3½
coil, inches	50	48	51·5	51	44	50	57
eels	4′ 8″	4′ 3¼″	4′ 3″	4′ 3¼″	4′ 2″	4′ 4″	4′ 3¼″
eels, inches	62	58	60	58	58	57	55
, whether independent	No.	Yes.	No.	No.	No.	No.	Yes.
iometric, Telescopic, norama or Ordinary	O.P.	T.G.	P.	P.	T.G.	O.	P.
n, calibres	29·2	30	30	30	28	31·4	30
on—wedge, swinging k, or eccentric screw	S.B.	S.B.	W.	W.	W.	S.B.	W.
shield, millimetres	5	4	4·5	5	4½	4	4
pivot or axle	P.	P.	P.	P.	P.	A.	P.
mber	36	32	33	40	32	38	30
agon limber	36	32	30	40	40	38	30
agon body	70	56	60	61	40	60	60
gun	358	296	168	242	192	332	210
agon, packed, cwt.	37	30·6	38·5	35·3	24	34	33·5
of H.E. shell	?	?	33	?	?	20	U.
guns in battery	4	6	6	4	4	4	4
wagons in battery	12	18	9	8	8	12	8*
	State and Ehrhardt.	Krupp.	State, Skoda, and Ehrhardt.	Krupp and Cockerill.	Krupp.	Schneider.	Krupp.

NOTES.—America: —358 rounds per gun includes
China: —The Skoda gun has been su
France: —The high explosive shell we
Germany: —126 rounds per gun, in ad
Holland: —The 6-gun administrative
Japan: —The figures given refer to
Norway: —The shield weighs only 56 l
Russia: —The ammunition includes 4
Spain: —The proportion of ammuni

CHAPTER XXXI.

MODERN QUICK-FIRING GUNS.

Weight of Gun and Carriage.

Two types of field-gun are in existence, a heavy and a light one. In both types the total weight of gun limbered up, with detachment, is kept within the power of a six-horse team. The proper load for such a team is variously estimated at from 40 to 43 cwt. But in the heavy type of gun the available weight is utilized in providing a gun of maximum power, with a small and light limber carrying comparatively few rounds; while in the light type the weight on the limber wheels is approximately equal to that on the gun wheels, and some 40 rounds of ammunition are carried.

The theory of the matter is as follows:—The advocates of the heavy and powerful gun hold that a Q.F. field-gun, to be of any use, must have a large supply of ammunition close at hand. That is to say that in action the gun must have a wagon holding say 100 rounds either close behind it or alongside it. Therefore the gun must *always* be accompanied by a wagon. This being so, the weight of the gun may be increased proportionally to the increased number of men available to handle it, namely, the men carried on the gun and the men carried on the wagon. If a detachment of five men can handle a gun weighing 18½ cwt., then seven men should be able to handle a gun of $\frac{7}{5} \times 18.5 = 25.9$ cwt., with equal ease.

On the other hand, the advocates of the lighter type hold that a gun which is dependent for efficiency upon the constant presence of its wagon is not wholly serviceable, and further that the unequal distribution of the weight upon gun wheels and limber wheels makes the draught considerably heavier.

The latter objection can be partly got over by carrying 3 gunners on the limber and none on the axletree seats, which are abolished. But it must be remembered that probably nine-tenths of the work on service will be done with the detachments dismounted. Opinions differ as to the best distribution of weight between the gun and limber wheels; but it is agreed that with the detachment mounted the weight on the limber wheels should not greatly exceed the weight on the gun wheels. Most authorities hold that for ease of draught the load on the leading wheels should be about four-fifths of that on the following wheels.

MUZZLE ENERGY.

The proportion of muzzle energy to weight of gun and carriage varies considerably, as is shown by the following table :—

	Weight of gun in action. cwts.	Muzzle energy foot tons.
France (1902)	22.4	333
Russia (1903)	20.75	373
Switzerland (Krupp, 1903) ...	19.75	245
America (Ehrhardt, 1903)......	21	300
England (1904)	24.75	324
Spain (Schneider, 1905)	20.4	267

It will be noted that the Russian gun is far more powerful in proportion to its weight than the rest. Of the remainder, the French gun easily surpasses the others. Even allowing for a saving of 1 cwt. by the use of the compressed air gear, the figures show that other nations have still something to learn from the French designers.

WEIGHT OF SHELL.

There is a further division of opinion among the advocates of the heavy powerful gun as to the weight of the shell.

A gun of given weight can fire either a light shell with a high velocity or a heavy shell with a lower velocity. The former has the advantage of a flat trajectory, tending to neutralise the errors in ranging and fuzing which much necessarily occur on service; the latter contains a larger number of bullets per shell. Since however the number of light shell which can be carried is proportionately greater than that of the heavier shell, the high velocity gun can put the same number of shrapnel bullets—and those more effective, owing to the flatter trajectory—on the target as the low velocity gun. But it will take a larger number of rounds, that is, more time, to do so.

Thus we see that the advantage of the heavy shell lies in *concentration of effect*. It is this undoubted advantage which has secured the adoption of the magazine rifle, which does not really fire any faster than the single-loader, but is capable of developing an intense fire-effect for a short period.

Whether in the case of the field gun this advantage counterbalances that of the flat trajectory is still an open question.

Two other arguments are urged in favour of the light shell. First, that since a large number of shell must be wasted in ranging, it is better to waste light shell than heavy ones. And second, that the most important duty of artillery is to attack shielded guns by making direct hits on them with high-explosive shell. Now a small H.E. shell, if it hits a gun, will disable the detachment as effectively as a large one, and the probability of hitting increases with the number of rounds fired. Therefore in this nature of fire the gun firing a large number of light shell has the advantage of the gun firing a lesser number of heavy ones.

So difficult is it to estimate the relative values of these conflicting considerations, that we find the three typical *heavy* field-guns which have so far been produced differing widely in ballistics. The French field gun, which was first in the field, fires a 15.96 lb. shell with M.V. of 1736 fs. The English gun fires an 18.5 lb. shell, M.V. 1590 fs.; and the Russian gun a 14.41 lb. shell, M.V. 1930 fs.

Where artillery scientists differ so widely, who is to decide? The question is rendered more difficult by the fact that most of the nations now re-arming have adopted a different nature of gun altogether—namely a light field gun, weighing not more than one ton unlimbered and of only moderate power. Thus Austria, Italy, Switzerland, Norway, Sweden, Denmark, Spain and Portugal—to say nothing of smaller states such as Roumania and Mexico—have all selected guns firing shell of from 5 to 6.5 kilos. (13.2 to 14.3 lbs.) with a velocity of about 500 metres, or 1640 fs.

RECOIL GEAR.

The German type of carriage, with hydraulic buffer and spring running-up gear, has held its own for several years. But lately the modern French type, with hydraulic buffer and compressed air running-up gear, has come into favour. Besides the French service gun, several hydropneumatic equipments such as the Portuguese gun, made by Messrs. Schneider, have now been in use long enough to prove their serviceability. The compressed air gear is certainly smoother in its action than springs, and is somewhat lighter. Provided that it can be relied upon on service, it would appear to be the better of the two. This view is confirmed by the good performance of the Spanish Schneider guns at Melilla.

TRAVERSING GEAR.

The axle-traversing gear, first introduced in the French service gun, was long regarded with suspicion. Possibly this was because it was associated with the admittedly clumsy method of *abatage*. But it appears to work very well in modern French equipments, and certainly gives a stronger and simpler carriage than the pivoted cradle.

SIGHTS.

The Goerz panorama sight has been almost universally adopted. Opinions differ as to the advantages of the independent line of sight, and the difficulty of fitting reciprocating sights to carriages of this type has militated against its introduction.

WHEELS.

England and America are the only Powers which use a 4ft. 8in. wheel. The Americans have been unable to reduce the height of their wheels on account of the badness of their roads. We cling to the large wheel because great mobility in a tradition in our service. All other nations have had to adopt wheels about 4 ft. 4 in. in diameter, in order to reduce the weight of their equipments.

SPRINGS.

The Russians, after their Manchurian campaign, have led the way by putting their ammunition boxes on springs and introducing spring limber-hooks and draught-loops. It is probable that other nations will follow their example.

SHIELDS.

It has now been recognized that it is impossible, within service limits of weight, to carry shields capable of resisting the new pointed bullets at ranges under 100 yards. The latest shields are therefore merely shrapnel-proof at all ranges, and bullet-proof over 500 yards. There is howevor a tendency to more extensive protection, and shields affording a certain amount of overhead cover (such as the Austrian shield) are now generally preferred.

HIGH-EXPLOSIVE SHELL.

England now stands almost alone in refusing to adopt H.E. shell for field artillery. Other nations consider these necessary for the attack of shielded guns, upon which shrapnel produce little effect. Explosives of the ammonal type are generally preferred, as having better keeping qualities than gun-cotton and being less sluggish than picric acid. Trinitrotoluol promises well. Combined shrapnel and H.E. shell are still in the experimental stage.

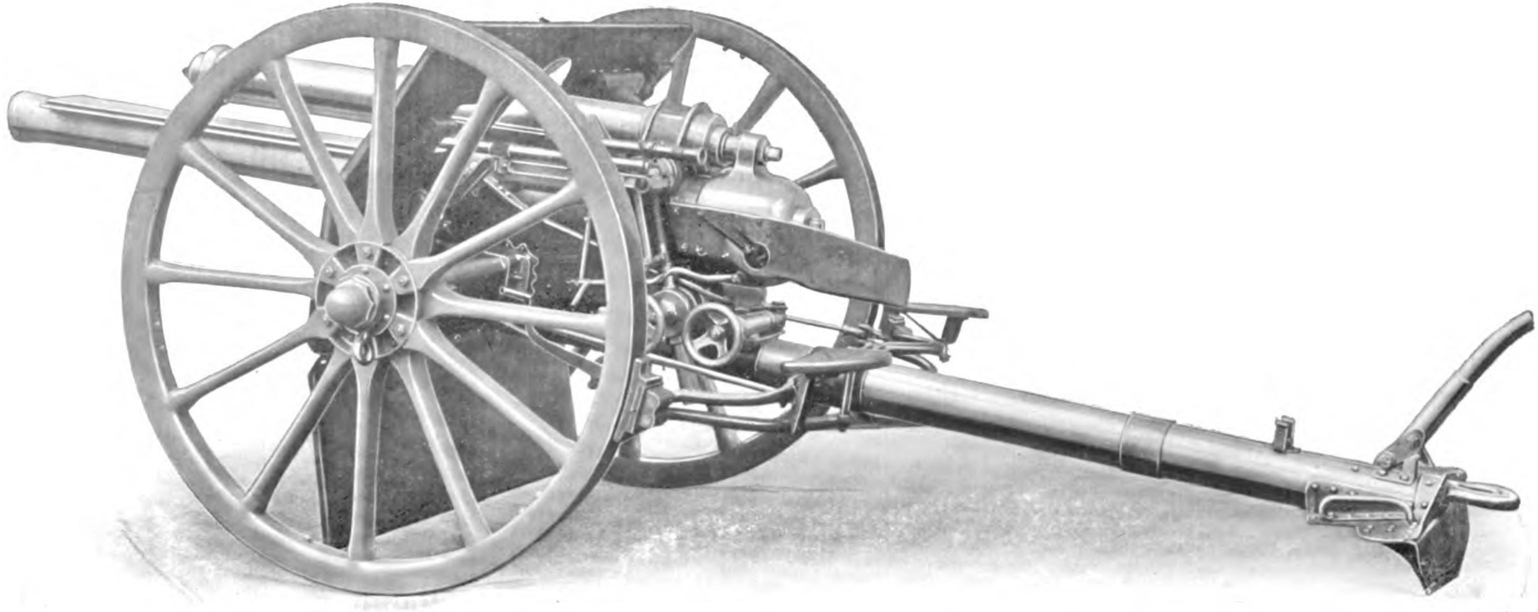
SHRAPNEL BULLETS.

The modern tendency in Europe is to reduce the weight of the bullet in order to get more into the shell. It is considered that even a slight wound is enough to disable a civilized soldier. Thus Italy, for instance, has reduced the weight to 9 grammes or 50 to the pound. Most other nations prefer 45 to the pound; but France, in view of the special ranging tactics adopted, uses heavy bullets weighing 38 to the pound. On the other hand, the Japanese, after the war, increased the weight of their bullets from 43 to the pound to 36.4 to the pound, and the Americans have done the same.

ORGANIZATION.

The question of 6-gun batteries has again been raised in France, on economical grounds, but French experiments carried out during the last three years have shown conclusively the superior efficiency of the 4-gun organization, which has been adopted by the great majority of foreign powers.

The Germans steadfastly refuse to allow more than one wagon per gun with the battery; they hold that all ammunition, beyond that in the limbers and one wagon-load per gun, should be carried by the light ammunition column, where it interferes less with the movements of the fighting troops.



18 pr. Q.F. GUN.
1903.

CHAPTER XXXII.

Q.F. GUN EQUIPMENTS OF DIFFERENT NATIONS.

THE 1903 ENGLISH Q.F. HORSE AND FIELD EQUIPMENT.

The 18 pr. Q.F Gun.

This gun is illustrated in the annexed Plates.

The Gun.

The gun is a wire-wound nickel-steel gun of 3.3 inches calibre. It has two guide-ribs extending for nearly its whole length. It recoils in a bronze ring cradle pivoted on the lower carriage. The cradle trunnions are set at an angle to the horizontal to compensate for the mean angle of drift.

Recoil is checked by a hydraulic buffer placed above the gun, surrounded by a set of telescopic running-up springs. (See page 123.)

The Breech Action.

This is of the cylindrical single-motion screw type described on page 100. On pulling the breech lever from left to right the effect is first to turn the breech screw through a quarter of a circle and then to withdraw it, the screw and carrier swinging round to the right. As the carrier swings, a cam on the hinge-pin engages the outer end of the extractor, which projects outside the breech; it first prises the cartridge case out of its seat, and then, with a sharper movement, ejects it to the rear.

The Firing Gear.

This is a repeating trip-lock. The striker is central, and rebounds within the face of the breech-screw after striking the cap. It is actuated by a tripper projecting from the left-hand side of the breech of the gun. When the breech is closed, the tripper enters a recess in the face of the carrier. The tripper is connected to a firing-lever placed conveniently to the layer's right hand. When the lever is pulled, the tripper first draws back the striker, compressing the main-spring, and then releases it.

The Elevating Gear.

A long elevating screw is set on the left-hand side of the trail. The lower end passes through a nut on the top carriage, the upper end through a nut on the cradle.

The Sighting Gear.

The gun has the independent line of sight (see page 91.) The sight is a rocking-bar pivoted on the left cradle trunnion, carrying a telescope and open sight. It is capable of traversing for deflection. The rear end of the bar is connected to a pivot in the centre of the elevating screw. When the lower nut through which the elevating screw passes is turned by the laying wheel, the gun, the screw, and the sight go up or down together; when the upper nut is turned by the elevating wheel, the gun goes up or down the screw without moving the sights. The angular movement of the gun with respect to the sight-bar is recorded on a range drum at the right-hand side of the cradle. To alter the elevation say from 4000 to 4300 yards, the elevating number merely turns the elevating wheel till the yard scale ring reads 4300, without disturbing the laying.

For laying on an auxiliary mark an all-round laying plane is fitted. This is a horizontal graduated circular plate fixed to the top of the shield, with a straight-edge and open sights. The graduations are similar to those on the battery telescope stand.

The clinometer is of the arc type, described on page 94.

Traversing Gear.

The gun and cradle are mounted on a small top carriage. This has circular flanges at bottom and traverses on a circular traversing-bed fixed to the axletree.

The top carriage is traversed by an endless screw engaging with its rear flange.

The Clamping Gear.

For travelling, the gun is clamped to the top carriage by an eccentric jamming clutch, so that there is no strain upon the elevating gear.

The Trail.

This is a straight steel tube secured under the axletree by stee loops. At the rear end is a fixed spade.

The Axletree.

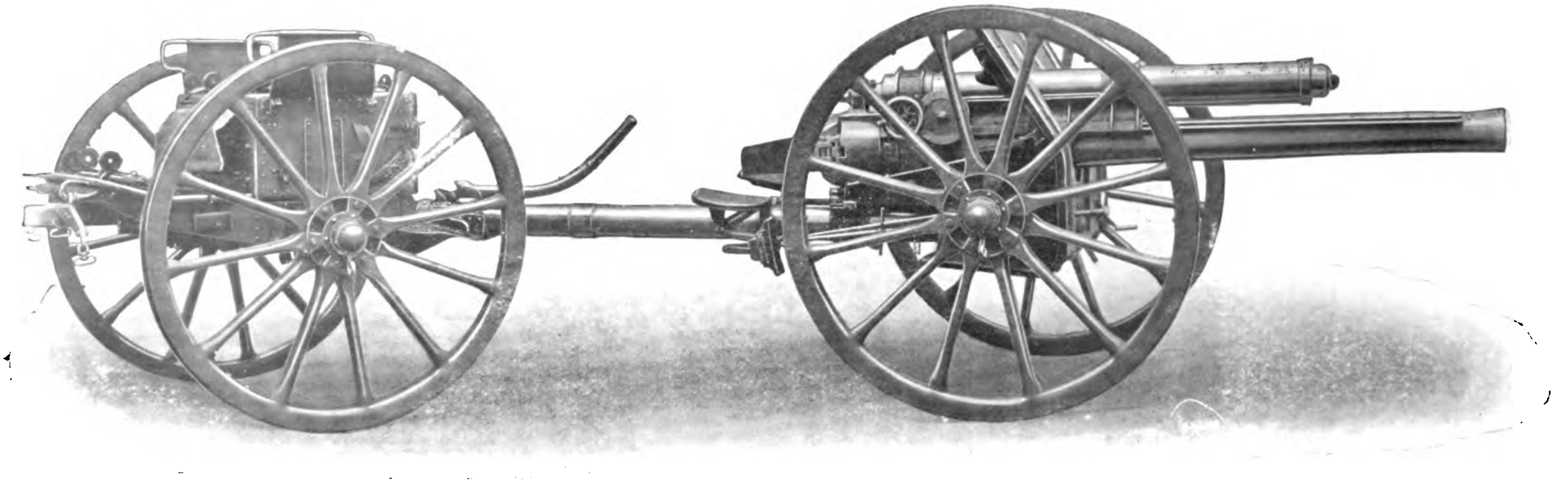
This is a hollow steel forging, square in the centre.

The Wheels.

These are of the double-strutted pattern with 14 spokes, 4′ 8″ in diameter. There is a cap to keep dust out of the pipe-box.

The Brake.

This consists of two arms carrying brake-blocks. The arms are hinged on the trail and are connected by tension-rods and bell-crank levers to a cross connecting-piece in front, so that if one tension-rod is shortened by a screw and hand-wheel both brake-blocks are pulled against the wheel. There is an eccentric link in the left tension-rod which allows the brake to be thrown out of gear if it is desired to shift the gun in action.



18 pr. Q.F. GUN.

1903.

The Shield.

This is of hard steel plate and is bullet-proof up to short ranges. The upper portion is curved backwards to give additional protection. The lower portion is hinged for travelling.

THE LIMBER.

This is a steel box limber very similar to the E.O.C. limber illustrated in the next chapter, but without the high guard-irons. It is divided into nine horizontal compartments; the central one contains tools and spare parts, and each of the others contains three basket-work tubes each holding a round of fixed ammunition. The door opens to the rear and hangs down to the ground, forming a shield for men working behind it.

THE WAGON BODY.

This consists practically of two limbers, the rear one having a perch instead of a pole. Each carries 38 rounds. The wagon, limbered up, is placed beside the gun in action, and the ammunition is handed straight from the wagon to the loading number. On top of the rear box is set the range dial, which is similar to the range drum on the ... Within the range dial is the fuze indicator, which can be shifted

Page 269, 3rd para.—The fuze indicator is no longer within the range dial, but is carried separately on each wagon and limber, so as to be in front of the fuze-setting numbers when at work

about the length of fuze, but simply orders "Corrector (say) 200," the fuze indicators are set accordingly, and the fuzes set at the graduation which appears opposite to the range ordered.

AMMUNITION.

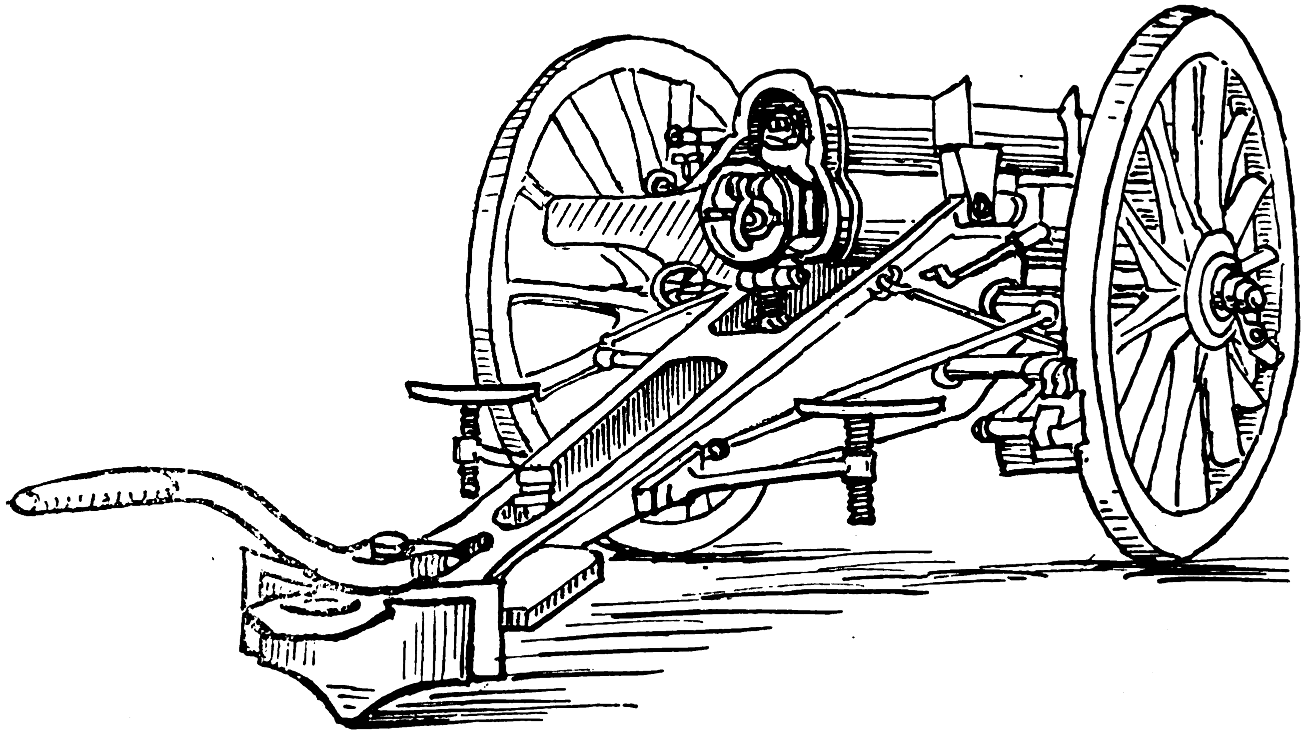
Fixed ammunition is used; it is always carried fuzed, and is similar in appearance to that shown in Plate opposite to page 157. Shrapnel only is carried. The fuze is on the same principle as that shown on page 162.

THE 13 PR. Q.F. GUN.

No separate description of this is required; the construction is simllar throughout to that of the 18 pr. Details of weights, &c., are given in the Table.

PERFORMANCE OF THE NEW EQUIPMENT.

The new guns are steady on firing and can be fired at the rate of 20 rounds (aimed) per minute. They are remarkably accurate, being much superior to the 15 pr. Q.F., which is considered a good-shooting gun. The powerful 18 pr. shrapnel gives good distribution of bullets over a depth of 300 yards at medium ranges, and is effective up to 6500 yards. The sighting arrangements are excellent and the independent line of sight enables the ranging to be conducted far more quickly than with the old materiel. Altogether the new guns may be considered at least equal to those of any foreign power.



THE 15 PR. B.L. CONVERTED GUN.

FIG. 102.

The 15 pr. B.L. Converted Gun.

No details regarding the conversion of this gun have been published in England. The following description and sketch are taken from Roskoten's "Heutige Feld-Artillerie." Their accuracy cannot be guaranteed.

The gun has been made to recoil on the carriage by suspending it by guide-blocks from the guides of a ring cradle. This cradle has cross trunnions which are directly supported by the trail brackets. The gun is traversed by shifting the point of the trail laterally along the spade, which remains fixed in the ground. This is effected by the traversing lever, which is pivoted as shewn in the figure. The breech action and the ammunition are the same as before, and the carriage has been fitted with a shield, presumably similar to that of the 18-pr. and 13 pr.

The converted 15 pr. is a very serviceable gun, and is equal in power to the present German field gun.

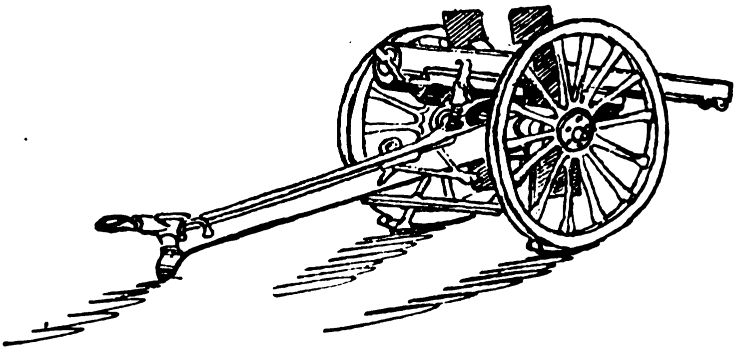


FIG. 103.

THE FRENCH 1899 Q.F. EQUIPMENT.

This was the pioneer of all modern Q.F. equipments, and still maintains its superiority in many respects over later designs.

The French gun is especially designed to give a far-reaching zone of shrapnel effect, which is required by the French system of fire-tactics. (See Chapter XXVIII.) It has therefore a flat trajectory, due to a high muzzle velocity and to a shell with high ballistic coefficient. It is a high-velocity 16-pr. of approximately the same power as our 18-pr. Q.F. gun. The shrapnel bullets (38 to the pound) are heavier than those used by any other European nation except Switzerland.

To obtain the high velocity of 1740 fs., the gun has been made of the unusual length of 36 calibres; and to keep it steady with the high muzzle energy resulting from this velocity, the diameter of the wheels has been reduced to 4 feet.

Page 271.—The gap between the two shields of the French gun has now been closed by a plate.

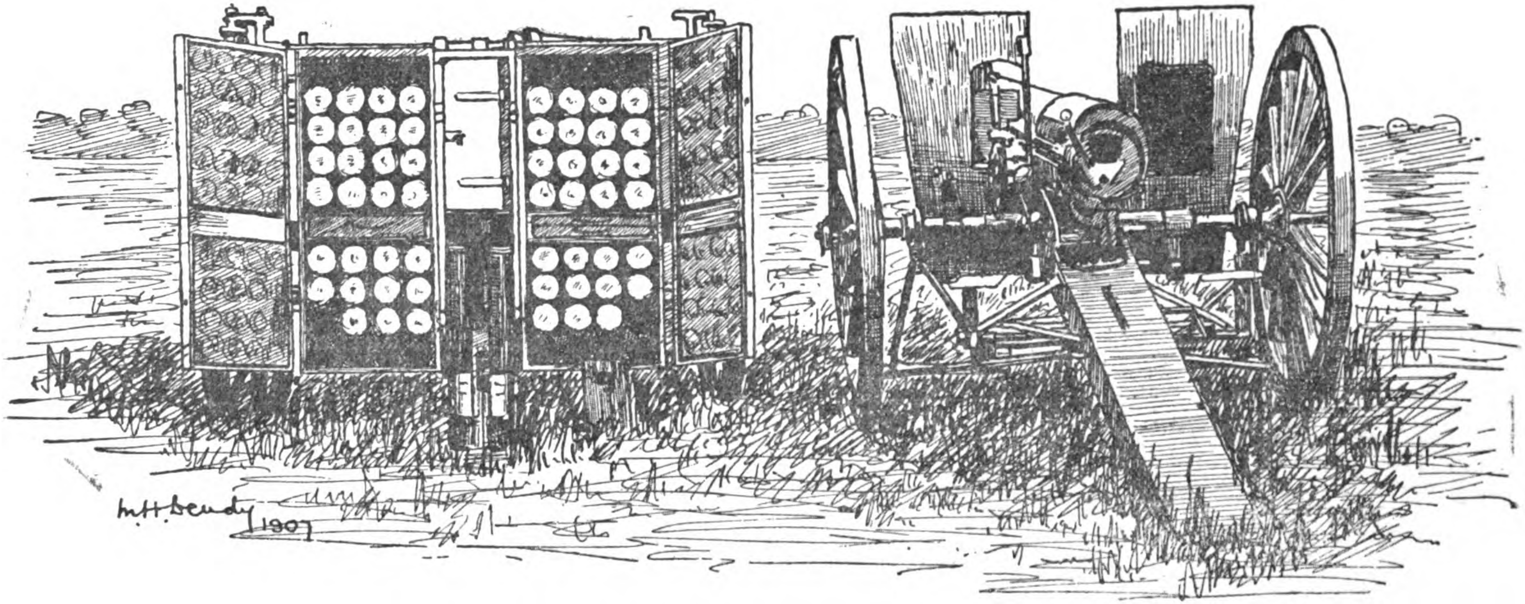


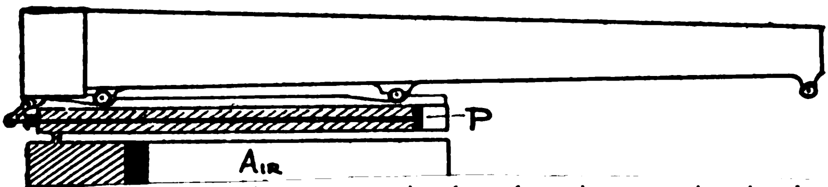
Fig. 104.

THE FRENCH Q.F. FIELD GUN.

The gun recoils on its carriage for a distance of 48 inches. The recoil is checked by a hydraulic buffer, and the gun is returned to the firing position by compressed air, acting on the buffer piston, at a pressure of 177 lbs. to the square inch. The carriage is perfectly steady during firing, and is held by a narrow pointed spade and by tire brakes which are dropped under the wheels so as to form drag-shoes. These brake-blocks have fins on the ground surface to prevent lateral movement.

The small projections seen below the muzzle in the figure fit under the cradle guides, and so support the gun in the extreme position of recoil.

The breech action is the Nordenfelt eccentric screw described on page 101. The gun is rifled with uniform twist, and the shell has a triple driving band (page 77.)



Page 273.—It is now certain that there is no spring in the air-chamber of the French buffer, except the valve-spring which regulates the resistance to the flow of the liquid. The air-chamber is in prolongation of the buffer, not under it as in the figure.

The exact details of the recoil gear are kept secret, but it is understood that the arrangement is in principle as shown in the above diagram. On recoil the piston P is drawn out of the buffer cylinder, forcing the glycerine through a narrow channel into the reservoir R. This reservoir is divided by a moveable piston M, the space in front of which is filled with compressed air, so that as the glycerine enters the reservoir the piston M is pressed forward, further compressing the air. On completion of recoil the air expands again, presses piston M back, and forces the glycerine back into the buffer cylinder. This forces the piston P to the front and so returns the gun to the firing position.

Since the gun was first designed, a helical spring has been added in the air-space to the right of the piston M. This has enabled the air-pressure to be reduced from 340 to 177 lbs. per square inch. Since the diameter of the air-cylinder is larger than that of the buffer, the travel of the spring is much less than the length of the recoil-stroke, and it is not liable to be crushed by firing. This system is known as "hydraulic reduction of the spring-stroke."

The gun recoils on rollers on the cradle guides; when in the firing position these rollers drop into inclined recesses in the guides, so that the gun then rests on the guides. This necessitates a jointed connection between the gun and the piston rod.

To traverse the gun, the gun and trail together are shifted laterally along the axletree by a nut engaging with a screw formed on the axletree.

In order to bring the gun into action, or to shift on to a fresh target, the trail has to be raised shoulder high to allow the brake-blocks to drop under the wheels; the trail is then dropped so as to bring the gun into the line of fire. This operation is called *abatage*. In other Q.F. guns the spade can be shifted laterally before the first round has been fired; but with the French gun the spade, once dropped, cannot be shifted. If, therefore, the gun is not pointing within 3 degrees of the target (the limit of the traversing gear) the operation of *abatage* has to be repeated. This undoubted disadvantage had led most other nations to choose guns with pivoted cradles or pivoted intermediate carriages in preference to those on the axle-traversing system. But it should be noted that axle-traversing guns of more recent construction, such as the Russian 1902 gun, do not require *abatage*.

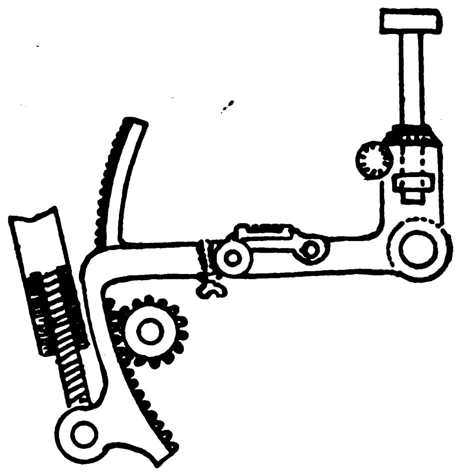


FIG. 106.

The gun has the independent line of sight, the pedestal sight being supported by a radius bar pivoted on the same horizontal axis as the cradle. The elevating screw is stepped on the rear end of the bar, and a toothed arc attached to the bar actuates the range dial on the cradle, which thus always marks the true elevation above the line of sight. There is no foresight, and the pedestal sight is used principally for direction, elevation being given by clinometer in metres of range.

In 1902 a shield was added, calculated to keep out infantry bullets at 400 yards. To compensate for the increased weight the axletree seats were removed, 3 gunners being carried on the gun-limber and 3 on the wagon-limber.

The shield is however admittedly unsatisfactory, affording no protection from oblique fire. It is proposed shortly to replace it by a shield of thinner metal (3.5 mm. against 5 mm.) but of greater area, and giving a certain amount of overhead protection as in the German and Austrian guns.

The French gun fires shrapnel and high-explosive shell, the latter filled with melinite, which is picric acid with the addition of a little mineral oil. It is detonated by an exploder of picrate of ammonia and saltpetre, enclosed in a stout metal tube or *gaine* projecting into the ~~melinite~~; the exploder is started by a detonate of fulminate of mercury. The H.E. shell weighs 11.65 lbs. only: it is of the thin-

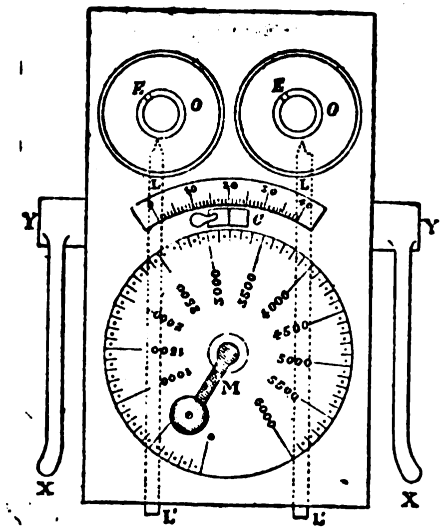


FIG. 107.

walled or "mine" type, and is said to contain 3.7 lbs. of melinite. The shrapnel fuze is illustrated on page 164. The fuze-punching machine is shown in the annexed figure. It may be seen behind the wagon in Fig. 103 with two shell inverted in it. The circular scale is graduated to the gun range; the arc scale is the corrector for adjusting the height of burst.

The shrapnel bullet alloy is 85 lead, 7.5 tin, and 7.5 antimony, specific gravity of pressed bullets 9.5.

The powder is pure gun-cotton, 50% soluble and 50% insoluble, in strips. It is not very regular and does not keep well. The primer is a dome of black powder moistened with soluble gun-cotton and compressed; it weighs 3 grammes.

In view of the experience of the Manchurian War the French have largely increased their reserve of ammunition.

The French mountain gun is described in Chapter XXXV. The ... Q.F. light field howitzer; the heavy

Page 275.—The French have now a 4.2″ and a 4.7″ field howitzer under trial.

Organization.

The French battery consists of 4 guns and 12 wagons; 6 wagon bodies are unlimbered with the battery in action. The other 6 wagons follow about a mile behind. This makes a total of 312 rounds per gun, of which 11.5% are high-explosive. In addition, the following rounds per gun are available: 188 in Army Corps' Ammunition Column, 500 in Grand Park, and 500 in Depôts, making a total of 1500 rounds per gun. But, as stated above, the number of rounds in the depôts has of late been increased, probably to 1000 per gun.

France has now 20 army corps, each with 92 field guns and 28,704 rounds, or 3.3 guns per 1,000 rifles, against, in Germany, 23 army corps, each with 144 field guns and 34,401 rounds, or 5.2 guns per 1,000 rifles. It is urgently necessary to increase the French artillery to make up this disparity. It has accordingly been decided to add 174 field batteries of four guns, besides 21 batteriesof 6 -inch Rimailho howitzers. As against this, 36 out of the 52 horse artillery batteries will be reduced. This increase will necessitate a reduction of the personnel of each battery from 5 officers and 103 men to 3 officers and 90 men. There will also be 120 nucleus field batteries, to be raised to full strength on mobilization.

These are called *batteries de renforcement;* the 30 batteries of an army corps have between them to form and train 6 nucleus batteries, making a total of 36 batteries with the army corps in war.

The total strength of the French Artillery is to be the following:—

64 regiments with 619 field, 14 mountain, 16 horse and 21 howitzer batteries in France, plus 15 field and 4 mountain batteries in Africa, and plus the 120 *batteries de renforcement.*

The re-organisation is to be completed by March, 1911.

The principal details of the equipment are given in the Table of Field Guns. The following additional details have been published:—

Total length of gun	8 ft. 10¾ in.
Number of grooves	24
Depth of grooves	0.5 mm.
Width	8 mm.
Height of axis	3 ft. 6 in.
Rate of fire per minute, about ...	15 rounds.
Height of shield	4 ft. 6 in.
Colour	Grey

Horse Artillery.

The French horse artillery are at present armed with the same gun as the field artillery. The weight has been somewhat reduced by removing the brake-blocks and gear, but the gun is still too heavy. Experiments have been carried out with the object of obtaining an

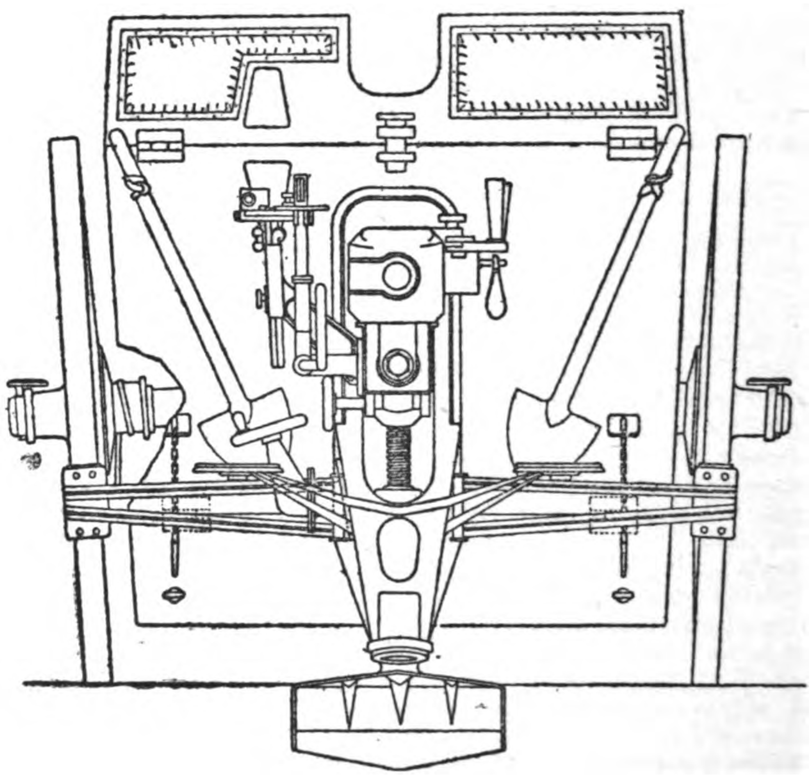


FIG. 108.
THE GERMAN Q.F. GUN, 1906.

Page 277.—The new French horse artillery gun will shortly be issued. It is of the same calibre as the field gun, and fires the same ammunition, but the muzzle velocity is reduced to 1550 fs. by removing a portion of the powder from the cartridge. Generally speaking, it is a smaller edition of the field gun, weighing 18½ cwt. in action and 27 cwt. behind the team. The buffer is of the Schneider pattern. The gun requires no *abatage*.

The German 1896 gun was a 15-pr. with spring spade, almost exactly equal in power to our 15-pr. B.L. gun.

In the new equipment, the old gun has been retained, and the gun has been mounted on a gun-recoil shielded carriage. It is now styled M. 96 n/A.

The Gun.

This has been altered by removing the vertical trunnion, shrinking on two chase-rings with guide pieces to slide on the cradle guides, and adding a horn to connect the gun with the buffer. The gun has been turned down and its weight reduced by 110 lbs. It is rifled with a twist increasing from 1 in 50 to 1 in 25 near the muzzle.

The Breech Action.

This is very similar to the Ehrhardt single-motion wedge shown on page 101. It is known as the Spandau action.

The Firing Gear.

The gun is loaded and fired from the right-hand side. A short padded pull is attached to the trigger of the repeating trip-lock; this is pulled out of the firing number's hand when the gun recoils.

The gun has three sights and a clinometer.

(a.) Ordinary open sights of the arc type, with an inner bar which draws out to make the fuze agree with the gun elevation (see page 85.)

(b.) On top of the arc sight is fitted a single-barrelled Zeiss prismatic telescope, set with the tubes side by side. This telescope has cross lines and gives a so-called optical line of sight, independently of the foresight.

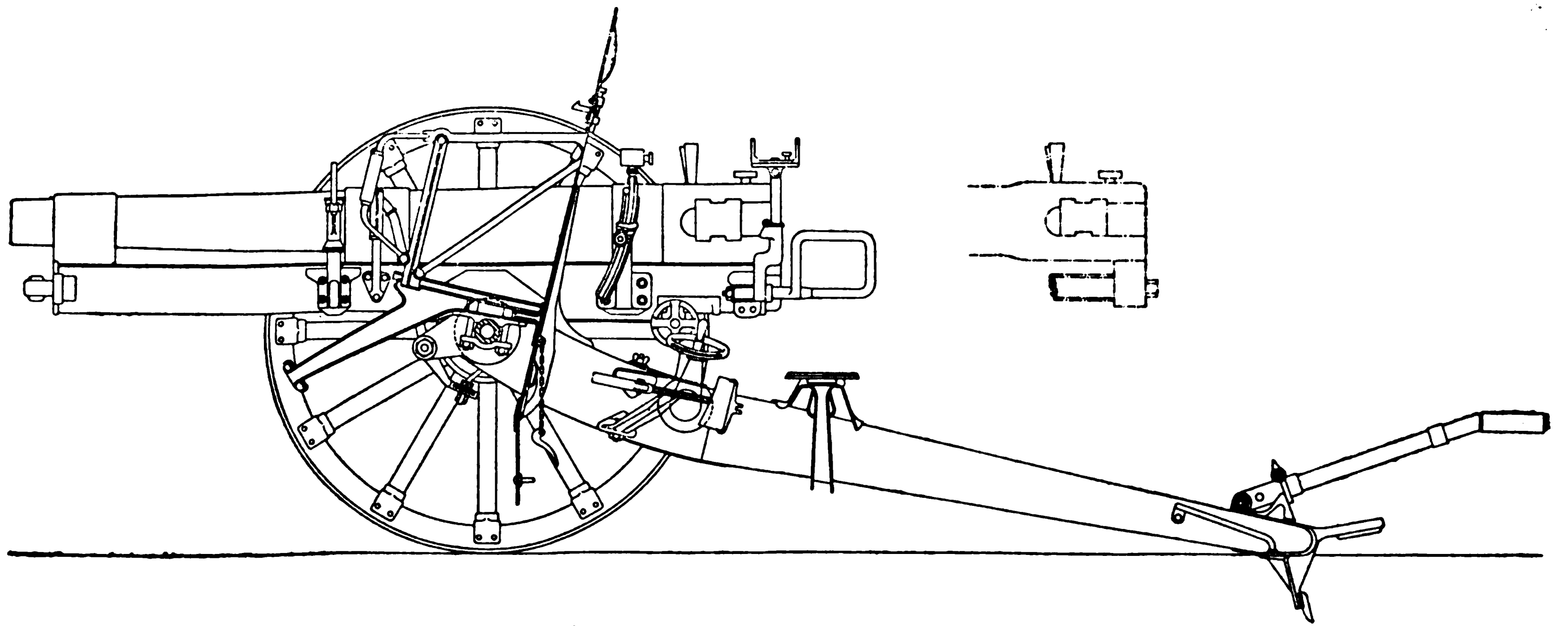
(c.) The laying plane is on the left of the gun, and consists of a graduated circle with sight-vanes and clamp. It is mounted on a standard to which a lengthening bar can be fitted in order to raise the laying plane so that the line of sight clears the top of the shield. This laying-plane cannot be cross-levelled, and is used for laying for direction only.

The gun has not the independent line of sight.

(d.) The clinometer is of the arc type, and is set on the bar of the arc sight, low down. The elevation given by it is read on the arc sight. The graduations on the face of the clinometer itself are for setting the angle of sight.

The Recoil Gear.

The buffer is of plain construction, without valves, and with a check-buffer plunger, as in Fig. 49.



THE GERMAN Q.F. GUN.
C. 96 n./A.
1906.
FIG. 109.

The recoil is 44 inches; this compresses the single column of running-up springs to only about half of their working length.

The Cradle.

This is a steel trough closed by a top plate, the upper edges forming guides for the gun. It has a socket underneath, which fits over a vertical trunnion fixed to a sleeve surrounding the axletree and capable of revolving about it.

The Traversing Bed.

This is supported on the elevating screw, and is attached by two stays to the axletree.

The Elevating Screw.

This is of the ordinary double-screw pattern. The spindle is prolonged so as to bring the elevating wheel in front of the layer's seat, so that he can use both hands to it. This seems to indicate a heavy preponderance.

Traversing Gear.

This is of simple pattern as seen in the figure. There is apparently no clamping gear for travelling.

The Trail.

This is a plain box trail, partly open on top to allow of 16½° elevation being given. It is slightly bent to give room for the elevating gear. Thc clearance under lowest point when limbered up is about 18 inches. The trail appears to be about 8′ 4″ long on the ground line. With the low muzzle energy (241.7 foot-tons) and 44-inch recoil, this gives a large excess of stability, and the carriage is perfectly steady in firing.

The Axletree.

This is straight and of tubular form. The central portion has annular ribs over which the sleeve carrying the vertical trunnion is fitted, so that it is free to turn about the axletree.

The Wheels.

These are the same as in the old equipment, namely 12-spoke wooden wheels, single strut, with spoke-shoes. A new pattern with spokes of hour-glass section is being introduced.

Brakes.

These are used for travelling only, and are applied from the off axletree seat. A flat braided wire rope, faced with leather, is attached to the brake-arm close to the brake-block. The rope takes one turn round a drum on the inner flange of the nave. When the loose end of the rope is tightened by a lever alongside the axletree seat, the wire rope grips on the drum, and the wheel as it revolves pulls the brake-block hard against the tire.

The Shield.

This is in three pieces, hinged horizontally, as shewn. It is set far back behind the axletree, partly for additional protection, partly to give room for the axletree seats. The height with top flap raised is 5 ft. 6 ins., and the area about 23 square feet.

The latest accounts state that the shield is 4 mm. or 0.1584 inch thick. This gives a weight of about 154 lbs.

Ammunition.

Fixed ammunition is used, consisting of shrapnel and H.E. shell, the latter filled with nitro powder. Both are fuzed with a T. and P. fuze which burns up to 5,000 metres. The cartridge contains 1.25 lbs. of tubular nitro powder. Three rounds of ammunition are packed in a basket.

The German authorities are experimenting with an *Einheitsgeschoss* or universal projectile which is to replace both shrapnel and H.E. shell. It is stated that the Government have ordered a large number of the Ehrhardt combined shell described on page 160.

Limber.

This is seated for three gunners. The figure shows the old pattern; the interior arrangements have now been altered to suit the new fixed ammunition. It is so balanced that there is no weight at the point of the pole when in draught.

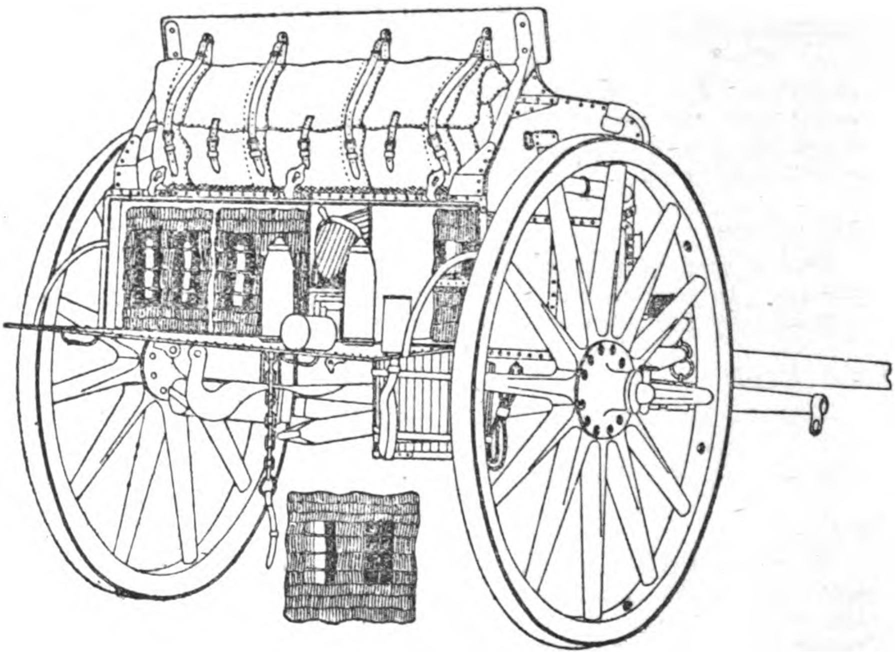


FIG. 110.

THE LIMBER.

Wagon.

It is stated that the present wagon body is to be fitted with shields in rear similar to those of our 18-pr. equipment. The wagon body is not tipped, but is unhooked beside the gun.

Organisation..

The battery consists of six guns and wagons. Five gunners are carried on the gun and 2 on the wagon.

Each battery is commanded by a captain; there are 3 batteries to a brigade *(Abtheilung)* and 2 brigades to a regiment. Each brigade has a light ammunition column attached to it, and each regiment an "artillery" ammunition column. Including light field howitzers, a German army corps has 5.76 guns per 1000 rifles, besides 16 heavy howitzers.

Ammunition Carried.

Each limber contains 36 rounds, and each wagon body 54 rounds. Thus with the fighting battery there are 756 rounds when limbered up, or 324 rounds when in action. Besides this, 36 high explosive shell are carried in the store wagon.

The light ammunition column carries 366 shrapnel and 264 high-explosive shell for each battery.

The artillery ammunition columns, of which there are eight in an army corps, one to each regiment of field artillery, including field howitzers, carry 691 shrapnel and 154 high explosive shell for each battery.

Thus a German battery takes into the field, including the ammunition carried in ammunition columns, 2267 rounds, or 378 rounds per gun, of which 80 per cent. are shrapnel and 20 per cent. high-explosive shell.

Weights and Dimensions.

These are given in the Table.

The following details have also been published:

Height of axis	37.75 inches
Weight behind the team with 5 gunners	43.25 cwt.
Number of grooves	32
Depth " "	0.75 mm.
Angle of opening of shrapnel, average	16 degrees
H.E. burster (gun-cotton powder)	5.45 oz.
Charge, tubular gun-cotton powder	1.25 lb.

Horse Artillery.

This is the same equipment, lightened by removing the axletree seats. The weight of the H.A. gun in action is given as 17¾ cwt.

Miscellaneous.

The equipment is now painted a brownish grey. Carbines have been issued to the gunners. It is in contemplation to substitute breast harness for collar harness.

THE AUSTRIAN 1905 Q.F. GUN.

(For many details given in this description I am indebted to a pamphlet published by Major Kuehn, Austrian Artillery. H.A.B.

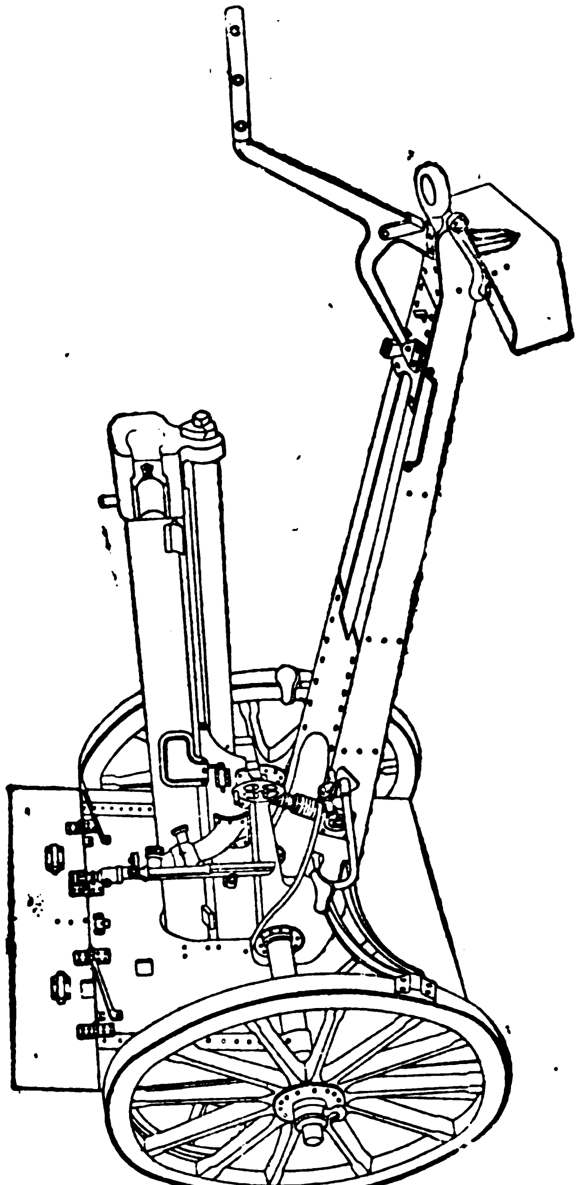
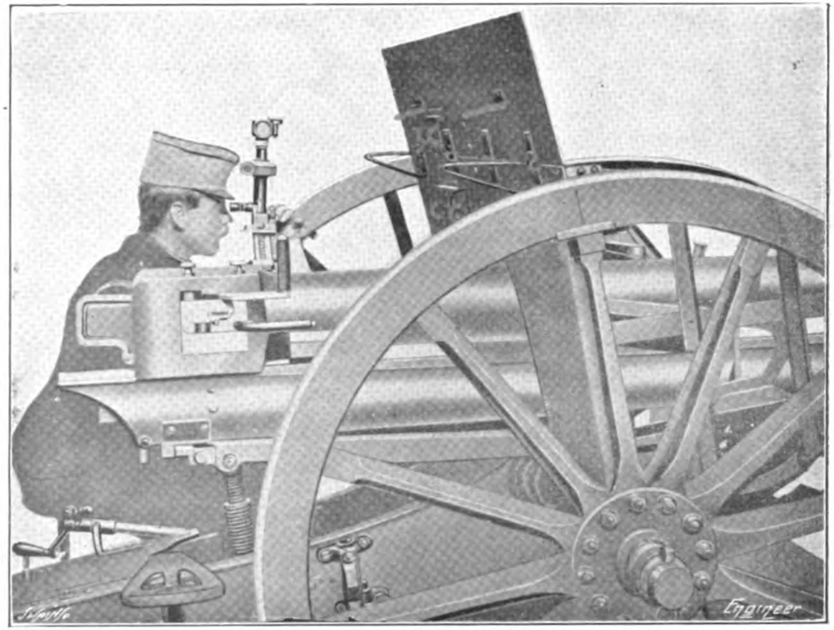


FIG. 110a.



THE AUSTRIAN Q.F. FIELD GUN, 1905
WITH GOERZ PANORAMA SIGHT.

This gun is remarkably similar to the Ehrhardt gun. The chief differences between the Austrian gun and the Ehrhardt 15 pr. in our own service are, that the gun is of bronze with a wedge breech and that a shield and panorama sight are fitted. It fires a 14.72 lb. shell with M.V. of 1640 fs.

The Gun.

This is of hard-drawn bronze, calibre 3.01 inches, rifled with 30 grooves, twist increasing from 1 in 45 calibres to 1 in 25. The breech action is very similar to the Ehrhardt action illustrated on page 101, but the lever is flattened and extended so as to form a cover protecting the recess in the upper face of the wedge from dust. The firing gear and extractor are the same as that described on page 103. The gun is fired from the right-hand side.

The sight is an arc sight similar to that on our 15 pr. Q.F. except that the sight-socket is pivoted parallel to the gun-axis and can be cross-levelled. The prolongation of the axis on which the sight pivots passes through the top of the foresight. For all-round laying a panorama sight is fixed on top of the arc sight.

The Cradle.

This is made by Ehrhardt, and is a steel tube of circular section with guides formed on top, along which the gun recoils. It has a vertical trunnion for traversing. This trunnion fits into a recess in a saddle pivoted on horizontal trunnions between the trail brackets; the rearward extension of the saddle forms the traversing bed, as in the Krupp guns.

The Buffer and Springs.

These are contained in the cradle, and are practically identical with those of our 15 pr. Q.F. The buffer is connected to the gun by a horn at the breech end and recoils with it. It is of plain construction, with ports and check-buffer; there is no running-up valve or Vavasseur valve. The check-buffer plunger has a small axial hole through which the liquid escapes when running up. The (single) spring-column consists of 5 springs, right and left-handed, without parting plates. The working length of the column is 74.5″, and it is compressed at full recoil (51.5″) to 23 inches, or less than one-third. This is a higher degree of compression than the German authorities have ventured upon, and is only possible with the best quality of springs, especially since these have to be stout enough to lift the gun at 17° elevation.

The Traversing Gear is the same as that of the German gun. See page 279. It gives 70 thousandths, or 4 degrees, right and left.

The Elevating Gear is an ordinary double screw, set centrally. The gun has not the independent line of sight.

The Trail is of box pattern, partly open on top. It carries a folding spade of unusual size, namely 8.25″ deep and 32″ wide. When the large spade is turned up there remains a small spur 3.5″ deep which is used on frozen or rocky ground.

Page 283.—The Austrians are experimenting with a half-charge for their guns, with the object of sweeping the front slope from the concealed position.

The Axletree is straight, with hollow arms.

The Wheels are of wood, slightly dished, plain metal naves. There are 12 spoke, single strut, of which 4 only (those at the junctions of the felloes) have spoke-shoes; the remainder have tongues. The wheel is 4′ 3″ in diameter.

The Brake Gear consists of two brake-blocks on pivoted arms, connected by tension rods with a cross-head in front. It is identical with the Ehrhardt gear on our 15 pr. Q.F.

The Axletree Seats are of sheet steel, perforated for lightness.

The Shield is practically the same as the German shield (page 280). But the top flap does not fold right down, but, when down, projects horizontally to the rear, giving a certain amount of over-head cover. It is 4½ millimetres thick, of special hard steel.

The Limber is much the same as that of our 15 pr. Q.F. It has 12 compartments, of which 11 contain each 3 rounds of fixed ammunition in a carrier. The door opens to the rear, forming a fuze-setting table. There is a large box on the foot-board for stores; kits are carried as on the German limber (page 280.) The most remarkable feature about the limber is the spring limber hook; this is on springs which allow it to move vertically, not fore-and-aft as in other equipments. This construction is adopted for the following reasons: The limber hook has to project some distance to the rear, in order to allow sufficient lock with a spade 32″ wide. The weight of the trail therefore exerts considerable leverage, and the play of the trail eye causes a corresponding play of the point of the pole. The spring which is interposed renders the motion of the point of the pole less jerky.—The swingle-trees are attached to spring draught loops.

The Wagon.

The limber is similar to the gun limber. The wagon body is of the high type, having 5 superposed rows of 4 compartments, each containing 3 rounds. The door hangs down to the ground, and there are, besides, two flap doors opening sideways, forming additional shields. The brake is of the South African pattern. The wagon body is unlimbered, not tipped, beside the gun; it has front and rear props. A spare wheel is carried on the perch.

Detachment.

Three men are carried on the gun limber, two on the axletree seats, and two on the wagon limber. There are no seats on the wagon body, which has a rail at top, and carries stores.

Ammunition.

Fixed ammunition is used; both shrapnel and high-explosive shell are carried. The former is similar to the Ehrhardt shrapnel illustrated on page 154; it contains a 3 oz. driving charge, 316 bullets at 50 to the pound and 16 at 35 to the pound. The fuze is similar to

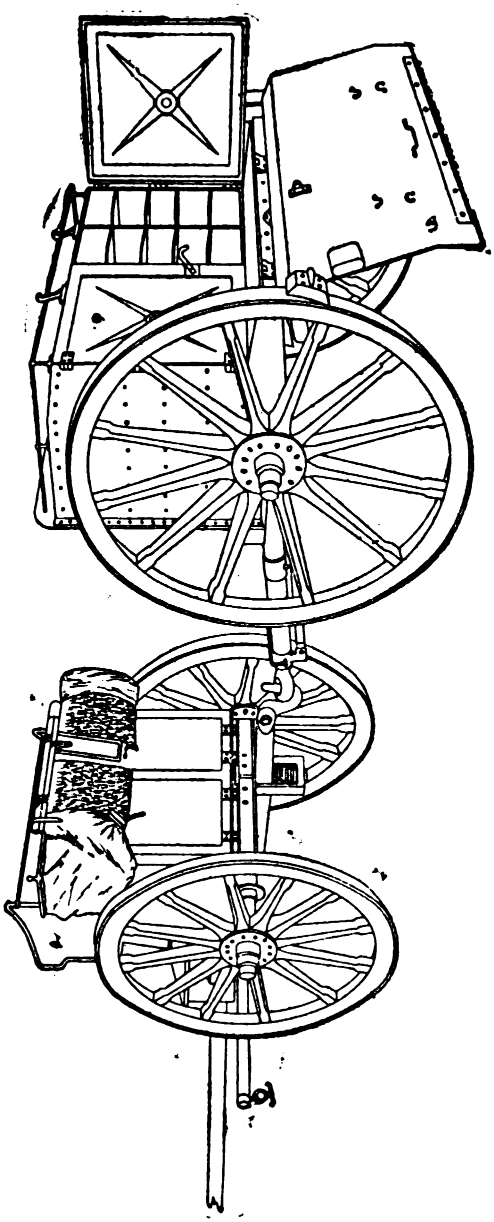


FIG. III.
THE AUSTRIAN AMMUNITION WAGON.

the Ehrhardt fuze (page 163.) The high-explosive shell is of the same weight as the shrapnel, namely 14.72 lbs., and ranges the same. It contains 7.5 oz. ammonal, and is fuzed with a T. and P. fuze.

Both shrapnel and H.E. shell have 2-diameter heads, and both have a forward copper centreing band as well as the usual driving band. The cartridge case is coned, and is similar to that of our 18 pr. The charge consists of 1.185 lbs. of tubular nitro-glycerine powder.

There is an automatic fuze-key, but no fuze-setting machine.

General Remarks.

This appears to be a simple and serviceable equipment of moderate power. Although fully shielded, the gun weighs only 1 ton in action. Eight numbers, besides the coverer, constitutes an unusually strong detachment; the object is presumably to be able to run the gun up to the crest when it is required to support the infantry by direct fire.

Page 286.—The Austrian shell has a long conical head, not an ogival head.

This was designed by General Engelhardt, and manufactured at Putiloff, Russia, in 1900.

This gun had a very high muzzle velocity, believed to be 1930 fs., and a shell of 14.41 lbs. The head of the shell was struck with an exceptionally long radius, namely 2.75 diameters. The gun fired fixed ammunition.

The Russian 1900 gun had no shield, the whole of the available weight being utilized in power. The arrangements for checking recoil were peculiar. The gun was mounted on a pedestal, which was arranged to ride upon the trail, and to slide down the trail in recoiling. The length of recoil was 3 feet. The trail was tubular, with a longitudinal slit in the upper surface. The buffer-cylinder was inside the trail, and the trail also contained the running-up springs, which were discs of india-rubber threaded on a spindie and separated by washers. The carriage was anchored by a spade and tire brakes. The breech action was a cylindrical interrupted screw, Schneider type, single motion. The sights were on the gun and recoiled with it.

The gun could be fired with the brake-cylinder empty, but was then unsteady.

THE 1902-3 RUSSIAN Q.F. EQUIPMENT.

The 1900 pattern Q.F. gun, used in the Russo-Japanese War, was a very powerful weapon, and its shooting gave great satisfaction. The equipment was however open to the following objections :—

(*a*) The gun was unsteady, requiring re-laying after every round.

(*b*) The sights recoiled with the gun.

(*c*) The india-rubber running-up springs gave trouble.

(*d*) The gun was too heavy for the country.

(*e*) It had no shield,

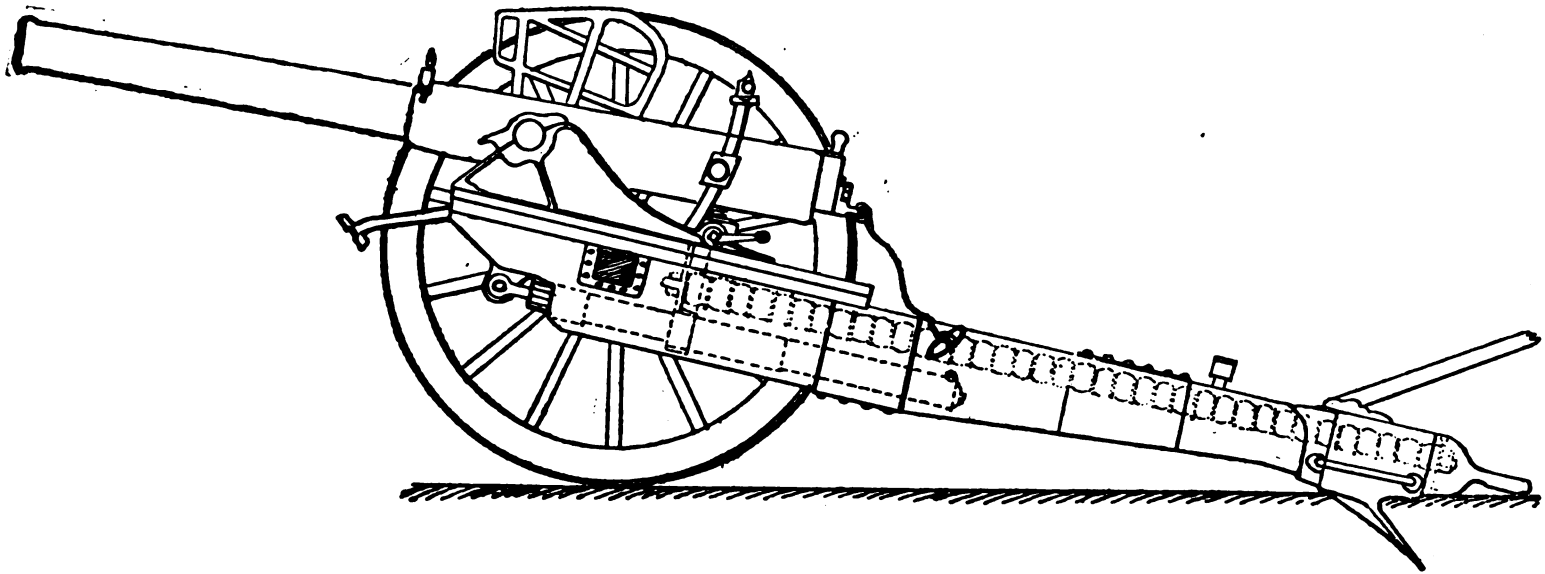


FIG. 112. THE RUSSIAN 1900 FIELD GUN.

It was accordingly determined to bring out a fresh design, preserving the high ballistics of the old gun (1930 fs. with a shell weighing 14.41 lbs.) and free from the objections to which the older gun was liable. The gun was known as the 1902 pattern.

In 1903 this equipment was again modified by removing the axletree seats and adding a shield and a panorama sight.

No drawings of the 1903 equipment are yet available, but it is identical, except as regards the above modifications, with the 1902 pattern, a description of which has been published by Captain Alexandrovitch of the Russian Staff.

The accompanying plate represents the 1902 gun. (Fig. 113.)

The Gun.

The gun is of nickel steel, calibre 3", 32 calibres long. It is rifled with uniform twist, 1 turn in 30 calibres. It consists of an "A" tube and jacket, secured at its forward end, 56.4" from the muzzle, by a locking ring. The guides, which are under the gun, are continuous, and are formed partly on the jacket, partly on a guide-piece, both ends of which are formed into rings shrunk on to the chase. The rear end of the breech-piece is extended downwards, forming a horn into which the buffer-cylinder is fixed. The breech-action is a single-motion cylindrical interrupted screw, generally similar to that of our 18-pr. Q.F., actuated by a hand-lever on top. It is intended for fixed ammunition. The firing gear is a repeating trip lock of very simple design. By pulling the tripper straight to the rear with a lanyard the striker is first pulled back and then released. The forked extractor is actuated by the carrier, which strikes it at the end of its swing, as in our 15-pr. Q.F.

The Sights.

The arc sight is much the same as that on our 15-pr. Q.F.; the foresight is hooded. The clinometer level is attached to the left-hand side of the arc sight, low down.

The sights and fuze are graduated in divisions, each representing 20 sagènes (140 feet) of range.

The dial sight is a simple circular laying-plane which can be set on top of the arc sight. It has two sight-vanes and a separate deflection scale. It does not correct for difference of level of wheels. In the 1903 equipment this laying-plane has been replaced or supplemented by a Goerz panorama sight which can be fixed on top of the arc sight.

The Cradle.

This is a steel tube, carrying guides for the gun on its upper surface. It has no traversing movement, but is mounted on horizontal trunnions on the trail. Traversing is effected by shifting the whole trail right or left along the axle. The cradle contains the buffer and running-up springs.

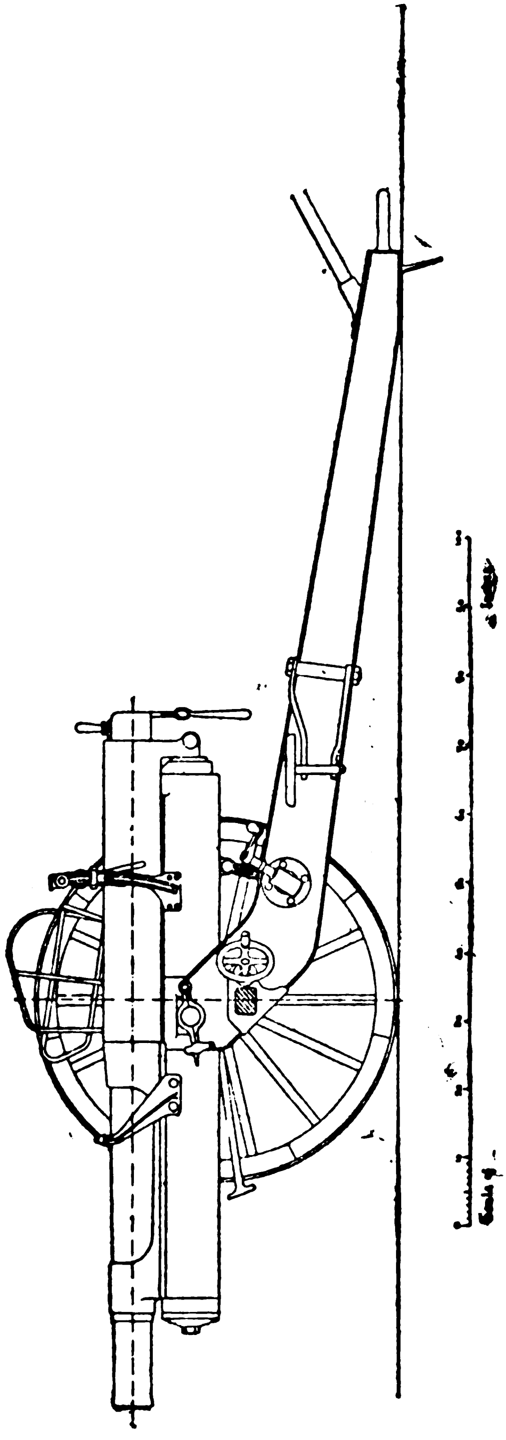


FIG. 113.
THE RUSSIAN 1902 Q.F. GUN.

The Buffer.

This is of novel construction. In ordinary buffers the graduated resistance to recoil is obtained by allowing the liquid to flow past the piston through channels or ports of varying depth formed in the inner surface of the buffer-cylinder. But in this equipment the piston is a close fit in the cylinder, and the liquid has to flow through holes in the hollow piston-rod formed just forward of the piston.

The hollow of the piston-rod is partly filled up by a tapered plunger fixed to the bottom, or rear end, of the cylinder,

The graduated resistance to recoil is obtained by varying the diameter of the plunger at different points, so as to alter the area of the annular channel through which the liquid has to flow. The buffer recoils with the gun ; the piston rod is fixed to the cradle.

The action of the buffer is shown in the accompanying diagram. As the gun recoils, and the stability of the carriages decreases, the annular space at *a* increases in area, so that the resistance to recoil, and consequently the overturning pull on the carriage, is reduced.

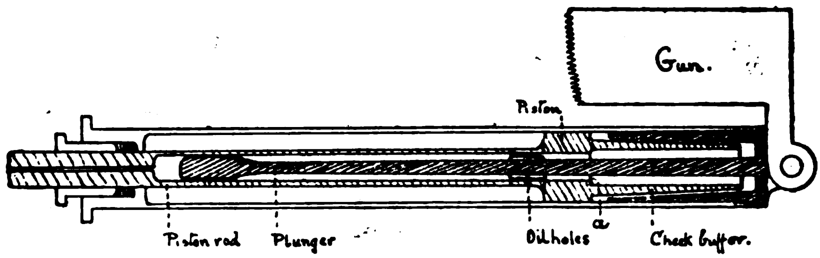


FIG. 114.

The Check Buffer.

To stop the gun at the end of the run-up, the rear end of the piston is prolonged to form a check-buffer, which enters a bell-mouthed tube fixed to the bottom of the cylinder.

With this recoil gear it was found that when the plunger was made to such a taper as to give the required graduated resistance to recoil, the annular space at *a* was too large to check the run-up properly. Accordingly the following arrangement (not shown in the diagram) was adopted:

The plunger is made stouter, and has an axial hollow through which part of the oil escapes during recoil. The oil obtains access to this hollow through three holes near the point of the plunger, closed during the run-up by a collar valve encircling the plunger and covering the holes. During the run-up the pressure of the liquid closes the collar-valve and the whole of the oil has to pass through the annular space *a*. At the end of the run-up the collar-valve nearly fills up the hollow in the piston rod, and brings the gun to a standstill. During recoil the pressure of the liquid on the collar-valve is relieved, and it is opened by a spring.

The buffer-liquid is light-gravity petroleum, which is said to alter but little in viscosity at low temperatures. The length of recoil allowed is 42.5 inches.

The buffer being completely filled with oil, there is a tendency to suck in air during firing, which prevents the gun from running-up (see page 118.) A stop-cock is accordingly provided at the stuffing-box end of the buffer cylinder, through which the air can be let off. The buffer is filled through the axial channel in the piston rod.

The Russian recoil gear, with the above modification, has been adopted by Messrs. Schneider of Creusôt, and is used in their new hydro-pneumatic equipment.

The Running-up Gear.

This consists of a single column of six helical springs of flat section. The springs are alternately right-handed and left-handed, and are separated by parting plates riding on the buffer. The spring column is 6′ 3″ long, and the springs are compressed on recoil into a space of 3 feet, or to rather less than half of their working length. The initial compression is about 5 cwt.

The Elevating Gear.

This is of peculiar design, and difficult to explain without a diagram. It consists of an inner screw hinged to the rear end of the cradle, an outer screw surrounding the inner screw, and a nut surrounding the outer screw. The nut is contained in a box pivoted between the trail brackets. The two screws are not, as usual, right and left-handed, but both right-handed. When the nut is turned the outer screw turns with it, since the friction between screw and nut is greater than between the two screws. The inner screw is screwed out as far as it will go, when the outer screw can turn no farther. As the nut continues to turn, the outer screw, now fixed, is then screwed out as far as it can go.

Should it happen that the friction between the screws is greater than that between the outer screw and nut, then the outer screw is first screwed out as far as it will go, and then the inner one.

This arrangement has the advantage of enabling screws with coarser pitch and stouter threads to be used for the same ratio of gearing. It is not otherwise attractive.

The gear allows of about 17° elevation and 6° depression.

The Traversing Gear.

This is simply a transverse screw fixed at one end to a projection on the axle, and turning in a nut attached to the trail. It gives about 2¾ degrees of traverse each way.

The Trail.

This is a box trail about 9′ long on the ground line, of the Krupp bent pattern. It carries a large fixed spade, a folding handspike, and seats for the layer and breech-closing number on arms which fold forward alongside of the trail. The front end of the trail carries the cradle trunnion-holes above and the axletree bed below. The latter is lined with bronze and slides on the rectangular axletree.

The Axletree.

This is a solid steel forging, cranked 4″ downwards in the centre in order to allow the gun and cradle to be set as low as possible.

The Wheels.

These are of wood, with 7 felloes and 14 spokes, dished, with bronze naves. They are 4′ 5″ high.

Dragshoes.

There are no brakes on the wheels. Two dragshoes attached by chains to eyes 2′.6″ from the trail eye are used both for firing and travelling.

Shield.

The exact dimensions are uncertain, but the shield is in 3 parts, either 4½ mm. or 5 mm. thick, and about 4′ 6″ high. The axletree seats have been removed.

The Limber and Wagon.

Russia, after her experience of draught conditions in Manchuria, has adopted springs on an extensive scale. All ammunition boxes are now supported on india-rubber block springs; spring limber-hooks and draught-loops have been fitted; and even the poles are bedded in rubber blocks. The seats on the limber and wagon are separate platforms formed of strips of wood, with india-rubber tubes interposed between them and the top of the boxes.

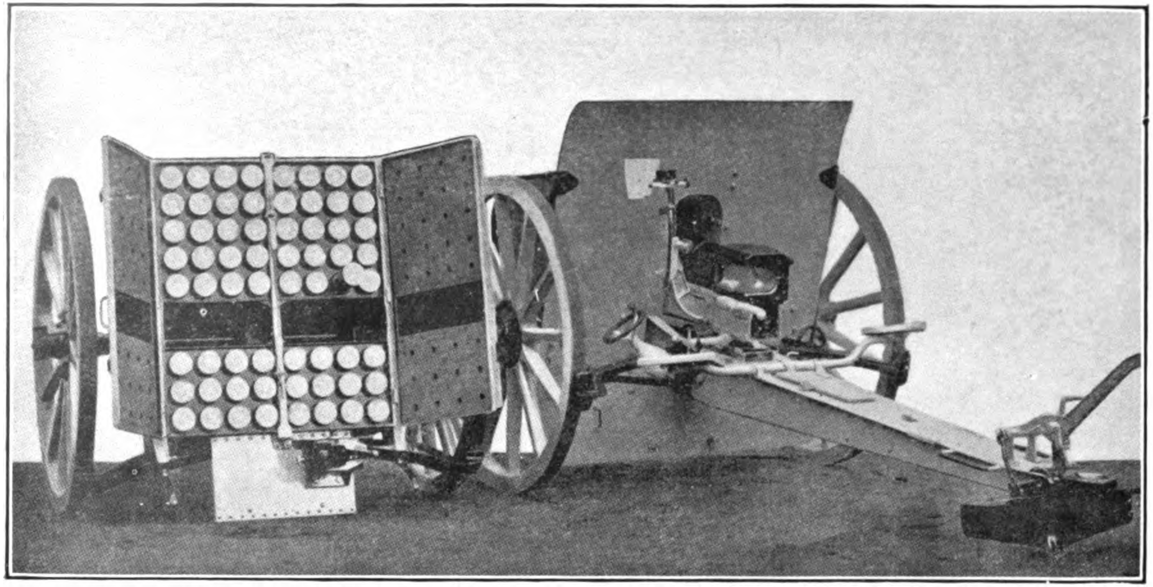
In action, the wagon body is unlimbered (not tipped) on the left of the gun, and somewhat behind it. The perch is to the front. The door forms a hanging shield. The ammunition is packed by fours in portable magazines. At present only 4 wagons are brought up into the battery for the 8 guns.

The Ammunition.

The gun fires fixed ammunition, shrapnel and high-explosive shell. The exact weight of the shell is still doubtful; it is probably about 14.41 lbs. It has a sharp head, said to be of 2.75 calibres radius. The shrapnel contains only 260 bullets of 42.5 to the pound, besides a driving charge of 3 oz. black powder and a smoke-producer of 1.34 oz., consisting of 45 parts magnesium and 55 parts phosphorised antimony. It is reported that 30 per cent of the shrapnel bodies break up when burst in flight, which is an excessive proportion. The bullet composition is 80 parts lead to 20 antimony.

The Russian fuze is similar in principle to the double-banked fuze illustrated on page 163, but the gases escape at the point of the fuze, which is hooded to protect the escape-holes from the air-pressure in flight. This precaution is very necessary in view of the high velocity of the shell. The fuze is covered with a tin cap luted to the shell, which is removed before loading.

The present high-explosive shell is similar to the French shell, which contains picric acid with a fulminate primer. A new pattern



THE SWISS Q.F. GUN, 1903.
KRUPP.

containing trotyl (T.N.T.) is under trial. The charge consists of 2.3 lbs. of pyro-collodion powder in strips. This powder is a nitro-cellulose intermediate between gun-cotton and collodion, and containing 12.5% of nitrogen.

Stability of Gun in Action.

Taking the values in the Table:—

Recoil velocity	34.4 fs.
Recoil energy	7.803 ft.-tons
Average pull on carriage	2.366 tons
Height of C.G. of recoiling parts above centre of spade	36″
Overturning moment, average	7.1 ft.-tons
Steadying moment, average	7.65 ft.-tons

Therefore the gun has a small amount of stability in hand at point blank elevation.

When the spade is sunk, and holding principally by its point, the height of the C.G. of recoiling parts above the fulcrum is increased, and it is not surprising to learn that the small amount of surplus stability allowed is insufficient to keep the wheels from lifting at low elevations.

The weights and dimensions are given in the Table.

The following details have also been published:

Height of axis	33 inches
Trail lift	116 lbs.
Weight of gun and recoiling parts ...	10.06 cwt.
Height of top of shield above ground	4.5 feet
Height of lower edge above ground ...	1 foot
Trail lift	116 lbs.
Clearance under gun	13 inches

General Remarks.

Except the new high-velocity Krupp gun, the 1903 Russian gun is the most powerful field gun in existence. It is somewhat heavy, but the design seems simple and serviceable. No great rapidity of fire is to be expected from it. According to Captain Alexandrovitch it recoils about 1 foot at the first round, and about 1 inch at each succeeding round.

The buffer, being completely filled with oil, tends to suck in air through the gland on recoil; this prevents the gun from fully running up, and the air has occasionally to be run off by a screw-plug fitted for the purpose.

Dragshoes are cumbrous things to use.

By using a cranked axletree the designers have succeeded in keeping the gun low, and in securing a fair degree of steadiness in spite of the high muzzle energy and comparatively short recoil. But some trouble has been experienced over the insufficient clearance under the gun, which is only 13 inches.

Altogether the design seems a good one, presenting several points worthy of imitation.

Horse Artillery.

The H.A. gun is the same as the F.A. gun except that the shield is smaller and thinner, so that the carriage is 45 lbs. lighter. The H.A. wagon and limber weigh less than those of the field gun and carry fewer rounds, namely 20 rounds in the gun limber and 24 in the wagon limber, as against 36 and 40, so that the weight behind the H.A. team is 32.7 cwt. as against 38.5 for the F.A.

Organization.

A Russian battery consists of 8 guns and 16 wagons, carrying 212 rounds per gun. Besides this, 600 rounds per gun are carried in the Mobile Park, and 200 in the Local Park, making a total of 1012 rounds per gun.

Switzerland.

The Swiss Q.F. equipment was the first made by Krupp, and has proved an excellent one, though it is now hardly up to the modern standard of power. The shell weighs 14lbs, and the M.V. is 1590 fs. In order to obtain good shrapnel effect it has been necessary to increase the weight of the bullets from 43 to 36 to the pound. (See page 206.)

The general appearance of the gun is shown in the annexed Plate. It differs from other equipments in that the track is narrower, being, for instance, 7 inches less than that of the 18 pr. This is in order to make the gun suitable for the Swiss mountain roads. There is no room for axletree seats, but two gunners can be carried standing on foot-rests. The gun is sighted with the Krupp dial sight illustrated on page 85. It has a folding spade with small fixed spur for use on rocky ground. The shield is hooded where it fits over the gun like that of the Roumanian equipment.

The high-explosive shell is filled with the same nitro-powder as is used in the cartridge.

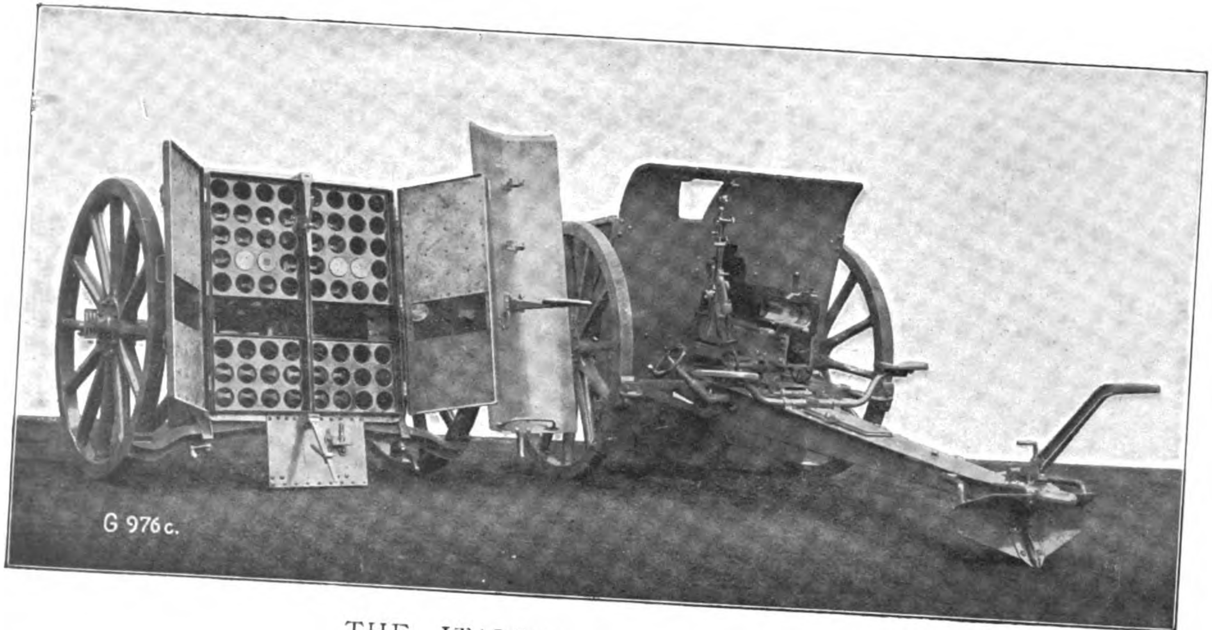
The following details have been published in addition to those given in the Table:

Height of axis of gun	39 in.
Track	55 in.
Width of tire	2¾ in.
Weight of carriage with accessories	13 cwt.
Pressure of trail on ground ...	154 lbs.
Weight of limber	15¾ cwt.
Shield, area of, square feet ...	20.5
Shield, weight of	167 lbs.

Italy.

Re-armament with the Krupp 14.3 pr. Q.F. gun is proceeding. Up to February, 1909, Krupp had delivered 642 guns. 430 more have been ordered to be delivered by November, 1911, of which 230 are to be completed, and 200 to be finished in Italy. Fourteen 4-gun batteries of heavy field howitzers of 149 mm. calibre have been ordered for the same date. The ammunition is to be made in Italy.

Page 294.—In addition to the Krupp guns already in the service, the Italians are manufacturing 600 Deport guns, to take the same ammunition. These are of the pattern described in amendment to page 136.



THE ITALIAN Q.F. GUN, 1906.
KRUPP.

The new gun is shown in the annexed Plate. It has the independent line of sight, with the Krupp reciprocating sight illustrated on page 93. The panorama sight is on top of the arc sight. The fuze-setting machine, when in use, is attached to the flap seen at the bottom of the wagon. The curved shield between the gun and the wagon is an observing shelter, with a step for the officer to stand on.

The carriage is of the ordinary Krupp construction with the cradle pivoted in a saddle on cross trunnions; these are inclined to com- [illegible]

Page 295.—The following additional details regarding the Italian Krupp equipment are now available:—The saddle on which the cradle is pivoted has a collar surrounding the axle as in the German gun. There is no foresight, but a collimateur, which also acts as a finder, is attached to the panorama sight. The gun can be fired either by a firing lever on the left-hand side or by a handle on the right-hand side as in the German gun. The upper portion of the gun-shield folds over to the front. The observer's shield shown in the Plate has not at present been introduced. The fuze-setting machine has a special arrangement by which, when a knob is drawn out, each successive fuze is set one graduation longer than the last; this is used when progressive fire is ordered. The limber has spring draught-loops and a spring limber hook; the latter is of the keyless pattern, the trail eye being held by a spring catch. The limber box is set low, the pole and axletree both passing through it instead of under it; the shell are carried vertically. The clearance under the box is about 14 inches. To open the box, the lid, with back-rest attached, is folded over to the front. The kits are carried as on the German limber. The wagon limber is the same as the gun limber. Steel poles have been issued, but it is intended to replace them by ash.

The project for converting the old 75/A guns to Q.F. has been abandoned, and 600 new Deport guns are being manufactured to replace them. See amendments to pages 136 and 294.

The Spanish gun is a good type of the Schneider equipments described in Chapter XXXIII. It is a 14.3 pr., M.V. 1640 fs., weighing 20.4 cwt. in action. It has a hydraulic buffer and compressed air running-up gear, and traverses on the axle. The general appearance of the gun is shown in the annexed Plate. It has the independent line of sight, with French *collimateur* (page 88) for all-round laying. The gun is rifled with a twist increasing from 1 turn in 130 calibres to 1 turn in 25. The charge is 1.475 lbs. of tubular gun-cotton powder No. 3. The high explosive shell is filled with *trilite*, which is the same as T.N.T.

The limber is fitted with spring draught loops and a spring limber hook.

Like all the Schneider guns, the Spanish gun is remarkably steady in action. Under peace conditions, no trouble has been experienced with the compressed air gear. Seven batteries of these guns are now at Melilla, and by all accounts these have done remarbably well. The gun is handy, perfectly steady when firing, and the mechanism has given no trouble whatever.

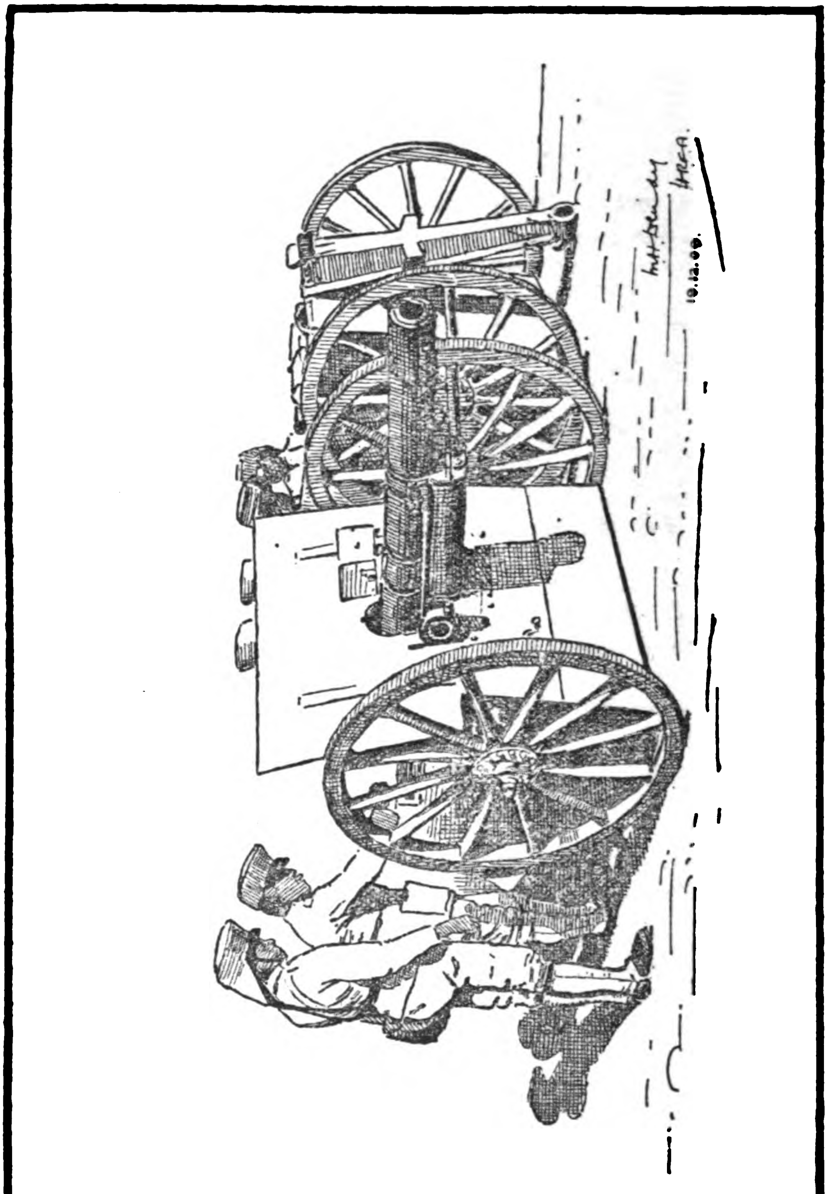
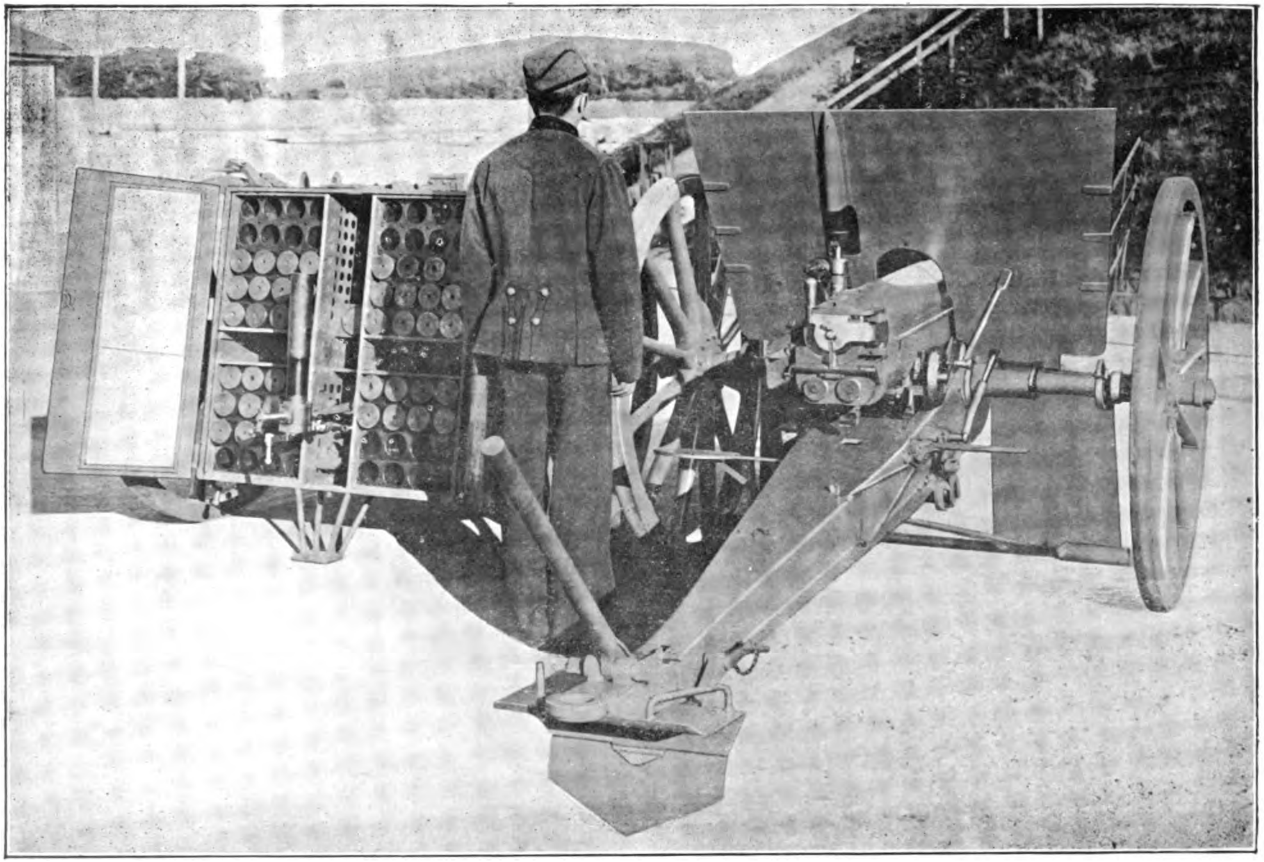


FIG. 1142. SPANISH SCHNEIDER Q.F. FIELD GUN AT MELILLA, 1909.



THE SPANISH Q.F. GUN.

SCHNEIDER, 1906.

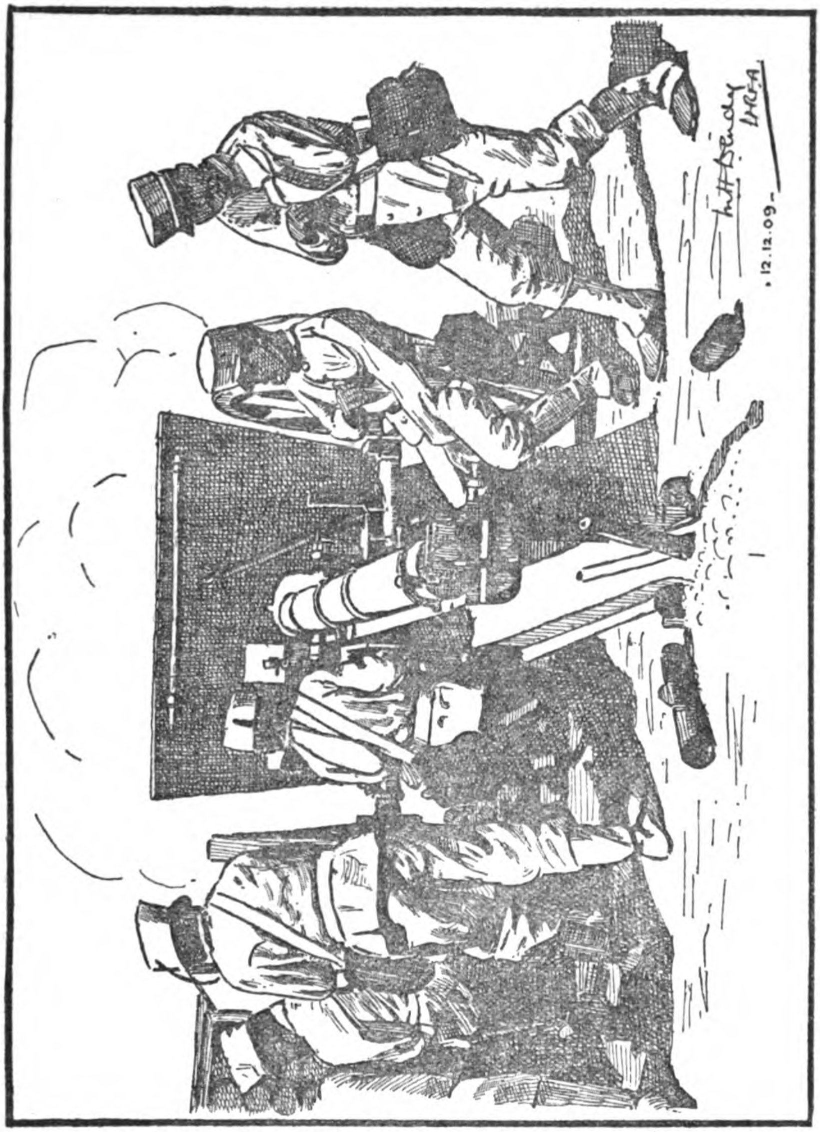


FIG. 114b. SPANISH SCHNEIDER Q.F. FIELD GUN AT MELILLA, 1909.

The Spanish High-Explosive Shell.

This is illustrated in Fig. 115. It is a stout steel shell carrying 10.5 oz. of trilite, which is the same as T.N.T. The charge is detonated progressively; the percussion fuze fires the column of black powder seen in the figure, giving a slight delay action. This ignites the detonator, consisting of 5.5 grains fulminate of mercury and 1 grain chlorate of potash. This detonates the first exploder, consisting of 7 grains of T.N.T. crystals. The detonator and first exploder are contained in the central copper tube seen in the figure. The detonation, thus started, is communicated to the second exploder, consisting of 1.5 oz. pressed ammonal, contained in a stout steel tube or *gaine*. The detonation of the exploder is communicated to to the main bursting charge.

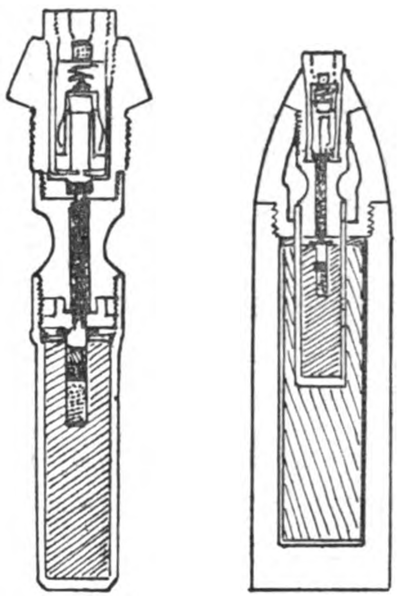


FIG. 115.

Portugal.

The Portuguese gun is similar to the Spanish but is slightly longer, and is rifled with uniform twist of 1 in 30 calibres. The gun and wagon are somewhat heavier. This equipment was selected in 1904 after a severe competitive trial with the Krupp gun. Except that the wheels had to be strengthened after the trials, this gun has proved remarkably serviceable. The buffers of the guns of the experimental battery were opened up for the first time after the guns had been two years in use, during which period they had fired an average of 1200 rounds each, and the gear was found in perfect condition, except that one packing required renewal. There is no loss of compressed air, but glycerine is lost during firing at the rate of one pint per 1000 rounds; this can be quickly replaced with a small force-pump.

An essential defect of the *collimateur* sight, used in this and in the Spanish gun, is that when an aiming point in flank or in rear is used the layer has to go outside the shield. It is probable that in course of time both of these equipments will be fitted with the panorama sight, which is free from this defect. But at present the heavy expense of providing these sights (the optical portion alone costs £25) stands in the way.

All graduations are in thousandths, and the battery telescope has ...ticule showing thousandths of range. The sight has a lengthen- ... raised for laying from behind a crest.

Page 298.—Spain has now added a fifth wagon to the fighting battery, containing 40 rounds of H.E. shell in the limber and 48 in the wagon body.

... as in the French ... gun-shield.

Page 298.—The Spanish artillery have adopted the Zeiss zig-zag sight described on page 91.

The gun has not the shoes under the wheels which characterise the French gun. These shoes are replaced by an ordinary travelling brake, which must however be slackened for traversing. The gun therefore requires no *abatage*. Presumably this simplification is rendered possible by the fact that the muzzle energy is much less than in the French gun, namely 266 foot-tons as against 333.

The carriage has axletree seats, but these are small and only intended to be used on emergency, the idea being to carry 3 gunners on the limber.

The limber has both spring draught-loops and a spring limber hook.

The weights of the equipment as submitted to the Portuguese Committee are given in the Table. But it is stated that these have since been somewhat increased, as the carriage and limber (especially as regards the wheels) were found too light for the Portuguese roads.

In addition to the ordinary fittings, the following are carried: an air-pump, a glycerine pump, (similar to a bicycle pump) and a pressure-gauge.

The gun fires fixed ammunition, including shrapnel and high-explosive shell. The latter contains a burster of about 1.25 lb., Schneiderite, which is a form of ammonal. The fuze is on the same principle as the Krupp fuze illustrated in the chapter on Ammunition, and is set by a fuze-setting machine. The gun is capable of firing 25 rounds in one minute with fuzes set beforehand, or 18.5 rounds per minute of searching and sweeping without setting fuzes beforehand.

The following details have been published in addition to those given in the Table:—

Length of rifling	77 inches
Number of grooves	24
Twist, uniform right-handed	1 in 30
Weight of breech action	26.8 lbs.
Height of axis	37.5 inches
Height of line of sight	44.5 inches
Trail lift	1.72 cwt.
Weight of one round	18 lbs.
Weight of shrapnel burster...	2.8 oz.
Pressure in bore, maximum	12.7 tons

Greece.

A competition was held at Athens in 1907, in which Krupp, Schneider, Ehrhardt, and Armstrong took part. The Schneider gun was selected on account of its steadiness and smoothness of action. It has compressed-air running-up gear and is generally similar to the Portuguese gun. Details are given in the Table. The Armstrong gun did best in the demolition trials, and the order for H.E. shell was given to that firm.

Turkey.

The gun is a Krupp 14 pounder, generally similar to the Swiss gun. The Turkish authorities required the gun to be fitted with plain arc sights only; there are no dial sights, and no means of laying the gun behind cover. It is stated, however, that a panorama sight is to be

Page 299.—The details of the Turkish gun are given in the Table; see also amendment to page 263. Turkey has 63 Q.F. batteries of these guns, 67 batteries of Krupp B.L. guns dating from 1873, and 52 Schneider guns intercepted *en route* to Servia in 1912. On the other hand, the Balkan Allies claim to have captured over 200 Turkish guns during the war.

The following details are given in addition to those in the Table:

Trail lift	... ...	124 lbs.
Shrapnel bursting charge ...	...	2.65 oz.
Powder, Rottweil D.F.P. ...	...	75 × 1½

Morocco has bought 16 guns from Schneider, similar to the Greek gun.

Bulgaria.

This is a 14.3 pr. Schneider gun, M.V. 1640 fs. The Bulgarians specially ordered a gun with springs. But after their experience with this gun they ordered compressed-air gear for their field howitzer and mountain gun equipments. Accordingly in January, 1909, they ordered nine 4-gun mountain batteries and nine 4-gun batteries of 10.5 mm. howitzers, of the regular Schneider pattern.

The field gun is much the same as the Portuguese gun, but has twin spring columns under the gun, on either side of the buffer. [redacted] occupy less vertical space than a single column and so allow [redacted] lower down on the axletree.

Page 300.—The Bulgarians had only 530 Schneider guns in 1911, but they decided to order 500 more. It is not known how many of these (if any) were delivered before the war.

... addition to those in the Table:

... cwt.

Weight o. -

Weight of charge, B.N. p...

Weight of shrapnel burster ... ...

Weight of H.E. shell burster, Schneiderite 4 oz.

Servia.

This is practically the same as the Portuguese gun. Schneider has supplied 45 four-gun field batteries and two horse batteries. 750 rounds per gun were originally ordered, but the supply has since been considerably increased. The old Du Bange equipment consisti...

Page 300.—The Servians ordered 160 more guns, 160 howitzers, and 150,000 shrapnel from Schneider, to be delivered in 1912. 52 of the guns were intercepted by the Turks before the war, and it is uncertain how many of the remainder have reached Servia.

... mountain guns
[redacted] inch and 4 6-inch

Page 300.—Montenegro has also 24 B.L. field guns purchased from Russia.

(See Figures 110 and 117.)

This is a characteristic Krupp gun, being a 75 mm. 14.3 pounder, M.V. 1640 fs.

The gun is of nickel steel, 30 calibres long, increasing twist, and has the Krupp single-motion wedge breech action. In this case it has no fore sight, but the Ghenea pedestal sight is used both for direct and for indirect laying. The gun has not the independent line of sight.

The Ghenea sight is peculiar in that the pedestal itself is mounted on a transverse horizontal pivot, to which the drum on which the elevation is set is attached. The pedestal itself is always perpendicular to the line of sight. The longitudinal level is just over the eye piece of the panorama sight; it is capable of adjustment for angle of sight. It is to be presumed that the saddle trunnions are inclined to compensate for drift, but there is apparently no means of compensating for difference of level of wheels.

The shield is a remarkable feature of the gun. It is 4 millimetres thick, and stands 5′ 9″ from the ground. Notice in the figures the conical hood projecting forward from the shield. The object of this forward projection is to keep the shield well back for protection and yet to bring the aperture through which the gun passes as near as possible to the horizontal and vertical trunnions on which the gun pivots, so as to reduce the opening to a minimum. Notice also the large shuttered window in the shield for convenience of laying. The lower shield is in two separate portions, one on either side of the trail. The shield is supported by two stays fixed to the front prolongation of the trail.

The brakes are of the ordinary pattern, but the handle is on the muzzle side; they are apparently intended for travelling only. There are no axletree seats.

The limber is seated for three; the weight of gun limbered up is only 33.8 cwt. without men or kits.

The wagon body is tipped beside the gun in action.

An observation ladder weighing 55 lbs. is carried on one of the wagons.

The shrapnel contains exactly 50% of bullets besides a burster of 2.65 oz. and a smoke-producing charge.

The high-explosive shell is a plain thick-walled shell with a central primer surrounded by a bursting charge of 4.93 oz. nitro powder; this again is surrounded by a layer of smoke composition. The double-banked T. and P. fuze weighs 13.8 oz. and the percussion fuze used with the H.E. shell weighs 12 oz.

The following particulars are given in addition to those in the Table—

Total length of gun	7.37 feet
Twist, increasing from 1 in 50 to 1 in 30	
Track, centre to centre	4.85 feet
Trail lift	154 lbs.
Thickness of gun-shield	4 mm.
Thickness of wagon shields ...	3 mm.
Weight of one round	18.75 lbs.
Length of shrapnel	3.5 calibres
Weight of 295 11-gramme bullets ...	7.15 lbs.

Roumania has now 102 4-gun batteries of these guns. 11 batteries, and one battery of 6 field howitzers, are allotted to each infantry division.

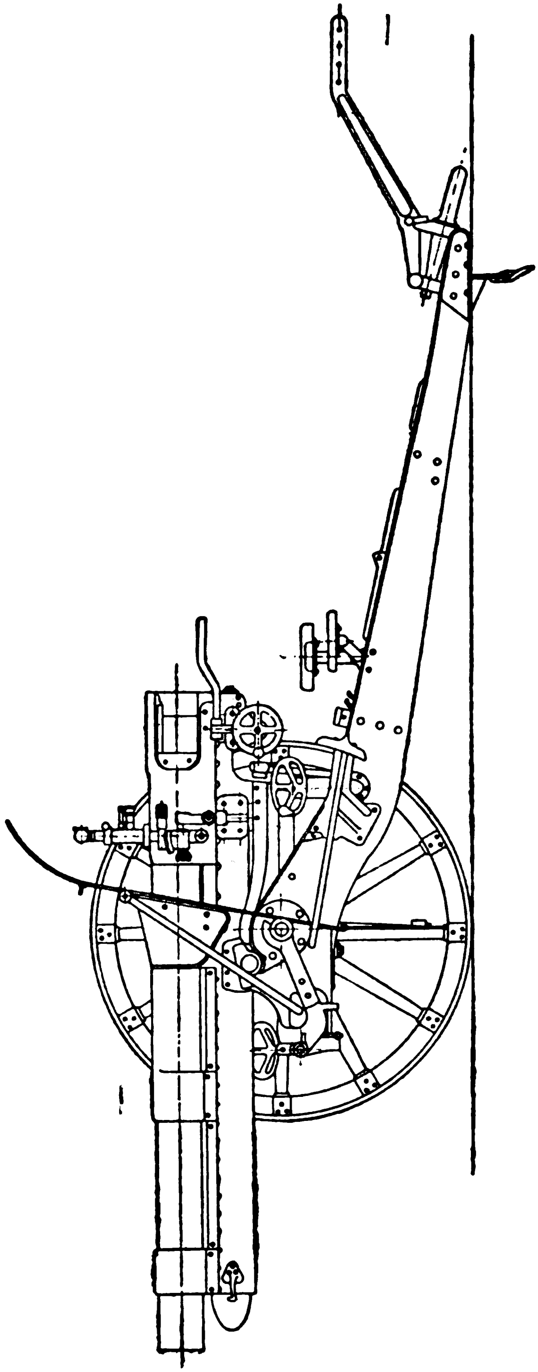


FIG. 116.
THE ROUMANIAN Q.F. GUN. KRUPP.
1904.

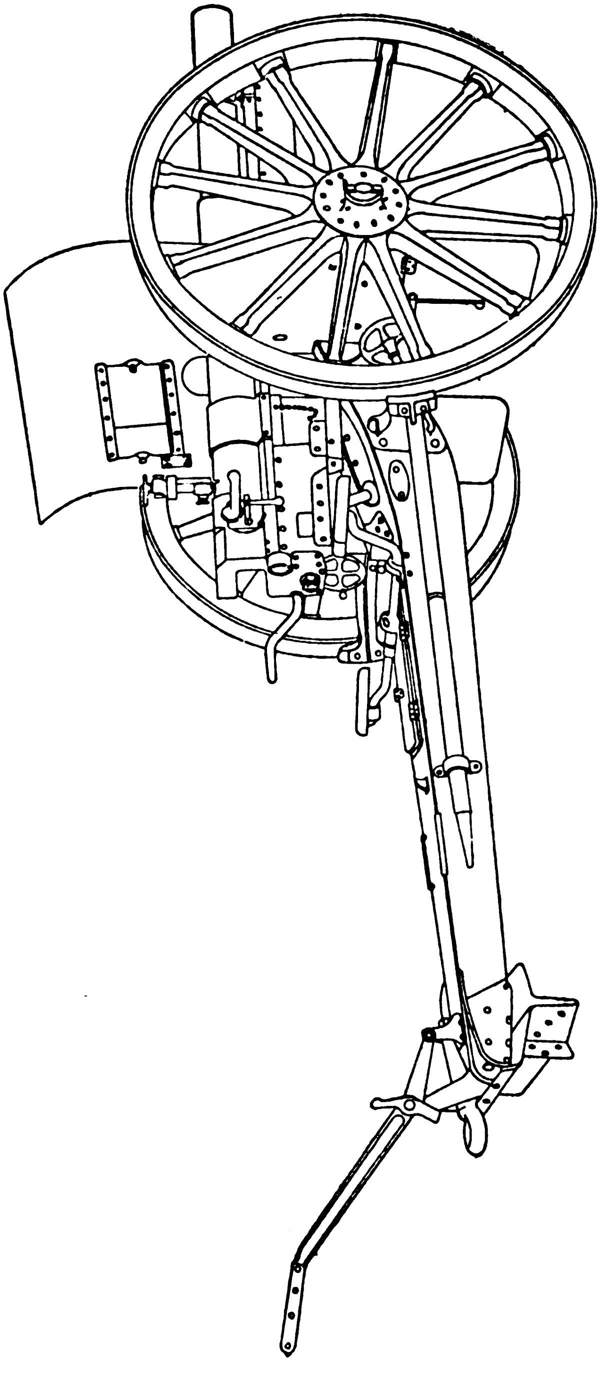


FIG. 117.
THE ROUMANIAN Q.F. GUN. KRUPP.
1904.

Norway.

This gun is made by Messrs. Ehrhardt, and is practically the same as the 15-pr. Q.F. gun supplied by the same firm to England, the chief difference being that the breech action is the Nordenfelt eccentric screw instead of the interrupted screw. The gun has been fitted with a folding shield 4′ 6″ high, and 3½ mm. or 0.14 in. thick, [redacted] There are still 6 guns in a battery.

Page 304—Norway has introduced the 4-gun organization, with 10 wagons per battery.

This gun is manufactured by Krupp, and is a somewhat lighter edition of the Danish gun described below.

The Swedes have adopted the leading features of the French system of fire discipline, namely ranging with time fuze, *tir progressif et fauchant*, and the *rafale*. They claim to be able to fire a series of 48 rounds of *tir progressif et fauchant* in 1½ minutes, without setting fuzes beforehand.

Denmark.

This is a 75 mm. gun, of Krupp's 1902 model, as illustrated in the Plate. It is more powerful than the Swiss and Dutch Krupp guns, firing a shell of 14.85 lbs. with M.V. 1640 fs. The gun is mounted on the usual Krupp cradle, pivoted for traversing on a vertical pivot set in a saddle between the trail brackets. The cradle contains the buffer, which recoils with the gun, and is surrounded by a single column of springs. The breech action is the single-motion wedg.. The gun is sighted with the Krupp telescopic sight illustrated on page 85. The elevating gear is a plain double screw under the traversing plate, which is a rearward continuation of the saddle. The firing gear is a repeating trip-lock; the gun fires fixed ammunition.

The shield consists of an upper and a lower portion. The upper portion may be removed and carried on the wagon for travelling; the lower portion is hung from the axletree. It is not continuous, but is in two parts, one on either side, which can be folded up backwards for travelling. The shield is 6 mm. or 0.236″ thick.

The wheels are 4′ 3″ in diameter. Axletree seats are provided, but three men can be carried on the limber. The limber is divided into 12 compartments, of which 11 contain baskets with 4 rounds; the 12th compartment contains tools and an automatic fuze-key. The wagon limber is similar, but carries 12 baskets. The wagon body is of the French type and is tipped alongside the gun in action. The bottom of the wagon is armoured with a 6 mm. plate, the doors with 3 mm. plate.

A pyramidal observation ladder can be mounted on the wagon. It weighs 48 lbs. and raises the height of the observer's eye to 10 ft.

The weight behind the team, without gunners, is 36.6 cwt. for the gun and 39.4 cwt. for the wagon. This is unusually high.

The following details are given in addition to those in the Table:

Height of axis	... ...	39.5 inches
Height of line of sight	...	49 inches
Weight of wheels	... ...	143 lbs.

Holland.

This is a Krupp field gun of very moderate power. It is of the characteristic Krupp construction described in the next chapter.

The shell weighs only 13.2 lb., and the M.V. is 1640 fs., giving a muzzle energy of 245 foot-tons, or slightly more than the 15-pr. B.L. gun. The equipment is not specially light, weighing 34½ cwt. behind the gun team without kits and without gunners. The Committee who selected it were impressed by the steadiness of the carriage in firing. Considering the low muzzle energy, it if not surprising that a high degree of steadiness was attained.

There is practically no advantage in having the carriage absolutely steady during firing so as not to require any re-laying. All that is really necessary is that the amount of motion should be so small that the layer is able to correct it in the 3 or 4 seconds available before the next round is fired.

Organization.

Holland has 30 six-gun batteries.

The principal details of the Dutch gun are given in the Table. ... also been published:

Page 305.—Krupp has supplied 30 14.3 pr. Q.F. guns to the Dutch colonial artillery. The gun has semi-automatic wedge breech action on the tappet system; an arm projecting from the breech mechanism lever strikes a projection on the cradle during the run-up. The gun fires universal shell. The weight in action is 10 cwt. ... construction is similar ...

Page 305.—In Holland each 6-gun battery is broken up into two 3-gun batteries on mobilization. There are 7 wagons per 3-gun battery. A proportion of universal shell is now carried.

Belgium.

This gun is a Krupp 14.3 pounder, M.V. 1640 fs. It is intermediate in weight and power between the Krupp guns made for Switzerland and for Denmark. It is of the ordinary Krupp build with buffer and single spring column under the gun. It is fully shielded with a 5 mm. shield. It has a panorama sight, but not the independent line of sight. The Belgians have imitated the Austrians in adopting the small shrapnel bullet, 50 to the pound. The idea is presumably that even a slight wound is sufficient to temporarily disable a civilized soldier, when he becomes a greater encumbrance to his side than if he were killed outright.

The gun fires fixed ammunition; the powder is Coopall's leaf powder.

The wagon is shielded, and is unhooked, not unlimbered, beside the gun in action. In addition to the rear door of the ammunition box, which hangs down to the ground, the box has two side doors opening outwards which give additional shield protection.

Details are given in the Table.

Persia has bought 8 four-gun batteries of field guns and 4 horse batteries from Schneider. This gun is understood to be a 13.2 pr., M.V. 1575 fs., weighing 18.5 cwt. in action and 31 cwt. behind the team. It ranges 6600 yards and is capable of firing 25 rounds a minute.

China.

China has bought 36 75-millimetre field guns and 184 mountain guns from Krupp, 36 field and 18 mountain guns from Schneider of Creusôt, and 110 guns from Japan. These are some of the light Arisaka guns used in the war. The Krupp gun selected is said to be similar to the Brazilian gun.

Japan.

The gun used during the war was designed by Col. Arisaka, and manufactured partly by Krupp, partly at Osaka, in Japan.

It is a light 75 mm. gun, adapted to be drawn by Japanese ponies It is not quick-firing, but the recoil is checked by large dragshoes and a spring brake.

The breech-closing mechanism is of the interrupted screw type, the breech-block being pivoted horizontally, so that it opens backwards and downwards.

Separate brass case ammunition is used, fired by a percussion lock.

The weight is kept very low; the axletree is in one piece with the gun, the trunnions being extended to form the axletree arms. In view of the rough ground on which the gun has to be used, the carriage is designed to allow a range of elevation and depression of 25 degrees.

The recoil is checked by large wedge-shaped dragshoes under the wheels; to these are attached wire ropes passing round drums inside the naves of the wheels and connected to a strong spring between the brackets of the trail. On recoil the wheels revolve backwards and the spring is extended; after recoil the spring contracts and rotates the wheels forward, tending to run the gun up again.

At the beginning of the Manchurian war the Japanese gun had no shield. But after the battle of Liao-Yang some at least of the Japanese batteries were fitted with gun-shields of boiler-plate. These shields may be noticed in photographs of the Japanese artillery on the Sha-Ho.

The ammunition consists of shrapnel and high-explosive shell; the latter has a bursting charge of picric acid, and a base percussion fuze with centrifugal safety. The fuze has a detonator of 40 grains of fulminate composition, and a primer of 2 oz. picric powder.

The gun is a 13 pr. with M.V. of 1500 fs. The weight in action is 17 cwt.

THE JAPANESE 1905 Q.F. EQUIPMENT.

The Japanese were dissatisfied with their light 1901 gun, the shooting of which compared badly with that of the powerful Russian gun to which it was opposed. Their new equipment is made to their own

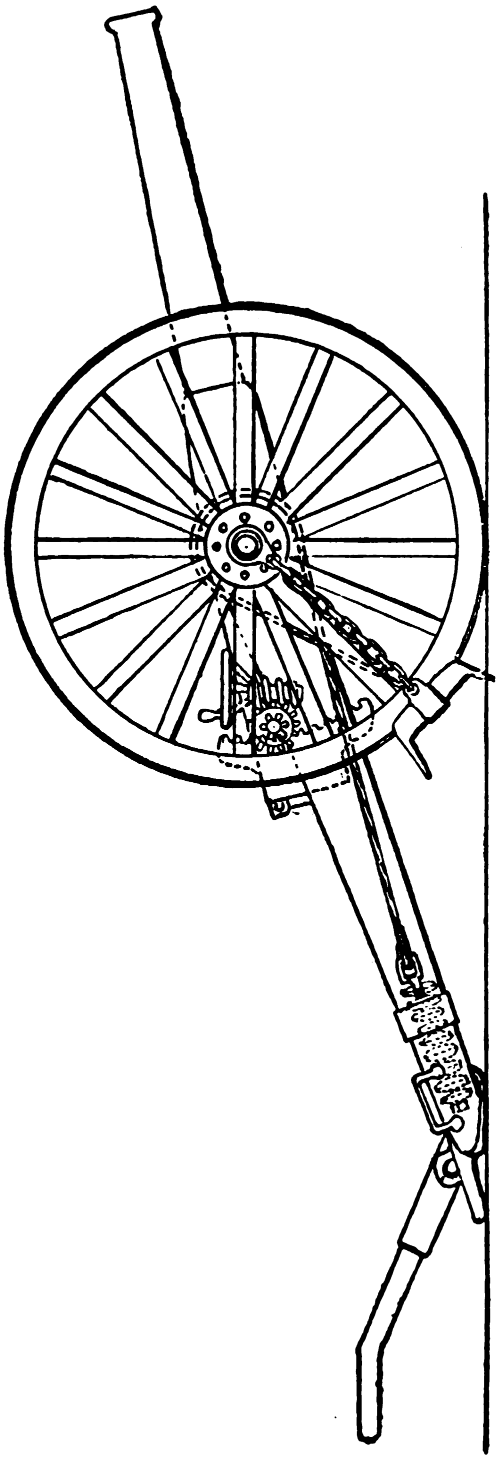


FIG. 118.

THE JAPANESE 1901 FIELD GUN.

design; it is a 14.3 pr. with M.V. of 1706 fs., generally similar to the Italian Krupp. The Krupp design has been lightened by omitting the axletree seats; the limber is of light pattern carrying 36 rounds. The track is narrower than that of the European guns, and is about 4′ 6″. The gun has a shrapnel-proof shield.

It is notable that after their war experience the Japanese have adopted a high-velocity gun and a heavy shrapnel bullet.

The present Japanese 14.3 pr. is to be superseded in time by a later pattern, which has compressed air running-up gear on the Schneider system in place of springs. It is of approximately the same power and weight as the present gun. Its issue has been deferred on financial grounds.

America.

This is a modernised version of the Ehrhardt gun as supplied to England. It has the Ehrhardt buffer and cradle with vertical trunnion set in a sleeve on the axletree, and a non-telescopic box trail 10 feet long. The buffer is peculiar in that the resistance is regulated

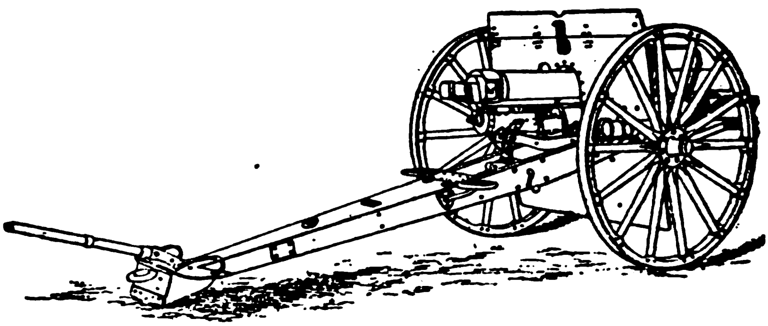


FIG. 119.

by tapering ribs fitting into notches in the piston, instead of the usual ports. The gun is rifled with twist increasing from 0 to 1 turn in 25 calibres at 10″ from the muzzle, thence uniform. The breech action is the Gerdom single motion interrupted screw, with 4 screwed and 4 plain sections. It has a percussion lock which is attached to the carrier, not to the breech-block. The breech-block is set 0.3″ eccentric, so that the striker cannot emerge from the block till the latter has been rotated to lock it. The extractor is in two pieces; the portion which ejects the cartridge moves in guides parallel to the axis of the gun; ths portion is actuated by the extractor lever, which is struck by the breech block as in the Ehrhardt action illustrated on page 99. This device seems unnecessarily complicated. The gun is fired by a firing-lever on the right-hand side of the cradle, which, when the gun is fully run up, engages with an arm projecting from the carrier. The gun can also be fired by a lanyard hooked into a ring on this arm.

Page 308.—U.S. America. The panorama sight is divided into 6400 *mils*, and is illuminated for night work. The fuze setter has a corrector which alters height of burst in *mils* (thousandths of the range). The wagon body has now a door opening upwards, besides a hanging shield. Each battery has 3 telephones and hand reels, and each regiment of 6 batteries has 2 telephones and a horse reel (telephone wagon). A proportion of universal shell are being issued.

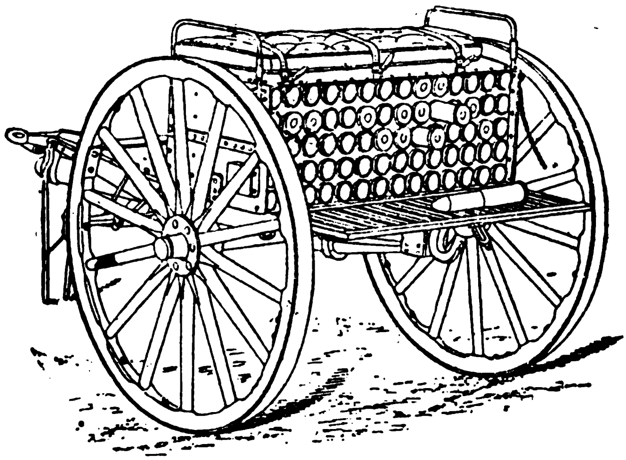


Fig. 120.

The elevating gear is the ordinary double screw.

The gun is sighted with an arc sight with a panorama telescope mounted on it. It has not the independent line of sight, but a device has been added which is intended to fulfil the same purpose. This consists of a quadrant graduated in yards on the right-hand side of the gun; a clinometer level can be shifted along this quadrant to the graduation correspondng to any desired range. When the layer has layed on the target, the clinometer, which is already set to the range, is inclined by a screw till the bubble is centred. The same lay can then be repeated (so far as elevation goes) by elevating or depressing the gun till the bubble is centred; or, if it be desired to alter the elevation, this can be done by shifting the clinometer along the quadrant scale before centreing the bubble. The quadrant is fitted with a cross-level, and can be revolved about an axis parallel to that of the gun to eliminate difference of level of wheels. A second elevating wheel is fitted for the use of the elevating number. Thus, after the first round, the layer lays for line while the elevating number lays for elevation by clinometer. The correct action of this device depends on the accuracy of the original lay. It is said to answer very well, and to give more regular laying than when the gun is layed by direct vision at each round.

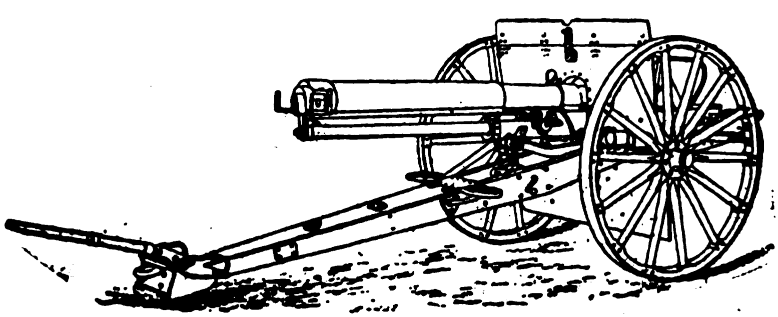


FIG. 121.

The brakes are of the ordinary pattern, but are applied to the firing front of the wheels. Ordinarily they are used for travelling only.

The shield is of special hard nickel tungsten steel, and resists penetration by the powerful American rifle at 100 yards. It is 5 millimetres or 1/5 of an inch thich, and has a folding flap at top which when erected stands 1 foot above the level of the wheels, which are 4ft. 8in. in diameter.

Four rounds are carried in steel tubes under the axletree seats.

The limber is of honeycomb construction, seated for 3 gunners. The wagon body is unlimbered, not tipped, beside the gun; it has a second limber hook in rear, to which the gun, or a second wagon body, can be limbered up on emergency. The latest pattern of wagon body differs from that shown in the figure in that the door opens upwards, forming an inclined overhead shield. There is a second shield which hangs down from the axle nearly to the ground. A simple fuze-setting machine, to set one shell at a time, is carried in rear of the wagon.

The wheels are 4′ 8″ in diameter; they have had to be strengthened since they were introduced, as the felloes proved too light.

The ammunition consists of shrapnel and high-explosive shell. It is noteworthy that the Americans have increased the weight of their shrapnel bullets; the original Ehrhardt shell had 315 bullets of 42 to the pound, while the present shell has 252 of 36.5 to the pound. The high-explosive shell contains 13 oz. of explosive. (See page 152). Ten per cent. of the shell are now fitted with Semple tracers (page 168).

The powder is cotton nitro-cellulose of 12.65% nitration, 99% soluble in ether alcohol. It is said to deteriorate after two years in store. It is now stained pink with rosanilin, which betrays incipient decomposition by changing colour.

The following particulars are given in addition to those in the Table:

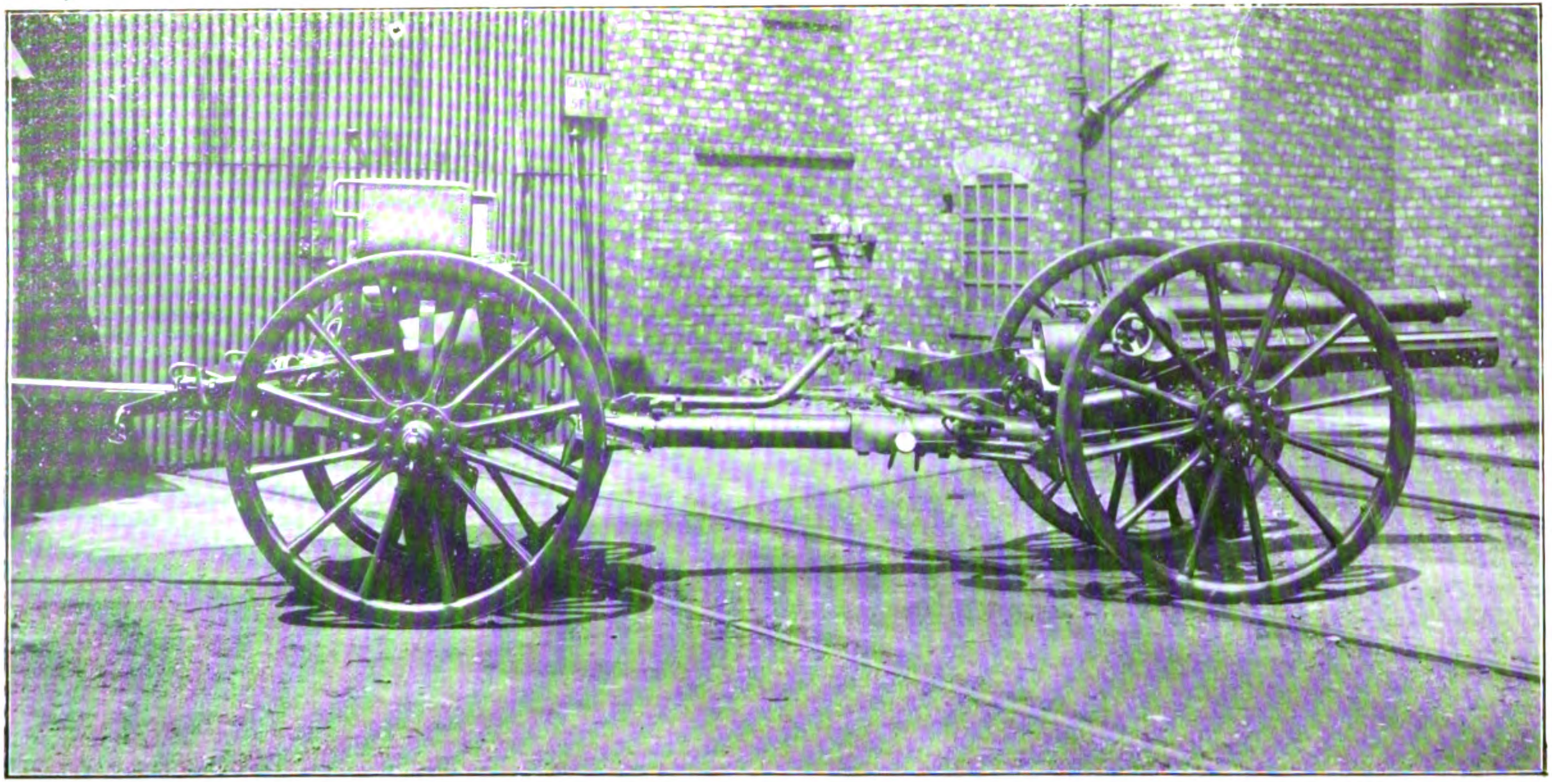
Extreme range with shrapnel	6500 yards.
Weight of one round	18¾ lbs.
Weight of limber empty	8¼ cwt.
Weight of wagon empty	18 cwt.
Weight of gun behind team with 3 gunners...	42 cwt.
Weight of wagon behind team with 6 gunners	44 cwt.

The above particulars refer to the 1905 model, but several batteries are still armed with earlier types of the same gun.

Mexico.

(See Plate.)

This is a high-velocity 13 pr. partly designed by Col. Mondragon of the Mexican Army, and manufactured by St. Chamond. It is a semi-automatic gun; that is, the breech opens automatically during running-up and ejects the empty cartridge case. The breech then remains open till the gun is loaded; when the extractor is pressed home in the act of loading the breech closes automatically by a spring, The action is similar to that of the Krupp semi-automatic mountain gun afterwards described.



ARMSTRONG 14.3 pr. LIGHT EQUIPMENT.
1906.

The semi-automatic action has been applied to light naval guns by Elswick, Vickers-Maxim, and the Coventry Ordnance Works in England, and by most of the great Continental firms. But the Mondragon gun is the only instance of its application to field artillery, with the exception of the Krupp and Deport mountain guns. It enables one of the men at the gun (the breech-closing number) to be dispensed with.

(It may here be noted that the French field artillery gun is practically semi-automatic. The gun recoils so that the breech is within reach of the "chef de pièce," standing at the point of the trail, and it is customary, though not regulation, for him to throw up the lever of the eccentric screw, so that the gun when it returns to the firing position is ready for loading.)

The Mexican gun is fully shielded with 5 mm. shields of chrome-nickel steel. The gun is run up by springs, not by compressed air. The peculiar method of attachment of the gun to the buffer, as seen in the photograph, is a St. Chamond speciality, and increases the effective length of the spring-column. The gun has a long box-trail, bent near the point, so as to allow of 16° of elevation being given. The spade is narrow and pointed, as in the French gun. The gun traverses on a central pivot. It is sighted with a panorama sight, and fires fixed ammunition.

The details are given in the Table.

The old Mexican 80 mm. (3.15″) B.L. guns have also been converted to quick-firers by the St. Chamond firm.

Brazil.

This is a light 13 pr. equipment made by Krupp. The gun in action weighs only 16 cwt., and the wagon only 24 cwt. The gun and wagon have 4½ millimetre shields. The gun is of moderate power; it fires fixed ammunition, and has not the independent line of sight. The breech action is the Krupp wedge.

Brazil has altogether 232 Q.F. Krupp field guns.

Details are given in the Table.

Argentine Republic.

This is a Krupp 13.2 pr., M.V. 1665 fs. It was selected in 1907 after a competition in which Krupp, Schneider, Ehrhardt, Armstrong, and Vickers Maxim took part. The three latter were 14.3 pr. equipments, and were considered too heavy for the country. The Committee reported both the Krupp and the Schneider 13.2 prs. suitable, with a preference for the latter. As however the guns already in the service were Krupp guns, the Government decided to adhere to the same pattern.

Several interesting points were noted during the trials. Thus the guns were originally about equally accurate, but after a severe travelling trial the Krupp and Schneider guns showed a marked superiority over the others. The Ehrhardt fuzes were the most regular. The Schneider gun was 2 cwt. lighter behind the team than the Krupp, but the wheels proved weak; the Ehrhardt wheels

were considered the best. The cordite used by Armstrong gave more regular velocities than the gun-cotton powder used by Krupp and Schneider, or the ballistite used by Ehrhardt. The highest rate of fire (26.8 rounds pei minute) was obtained with the Schneider gun.

The following details are given in addition to those in the Table:

A fuze-setting machine with corrector is provided.

The wagon body is provided with shields.

Weight of H.E. shell burster ...	2 lbs.
Track	4 ft. 5 in.
Weight of limber packed	13.5 cwt.
Trail lift	210 lbs.

The re-armament is to be completed by December, 1911.

Chili.

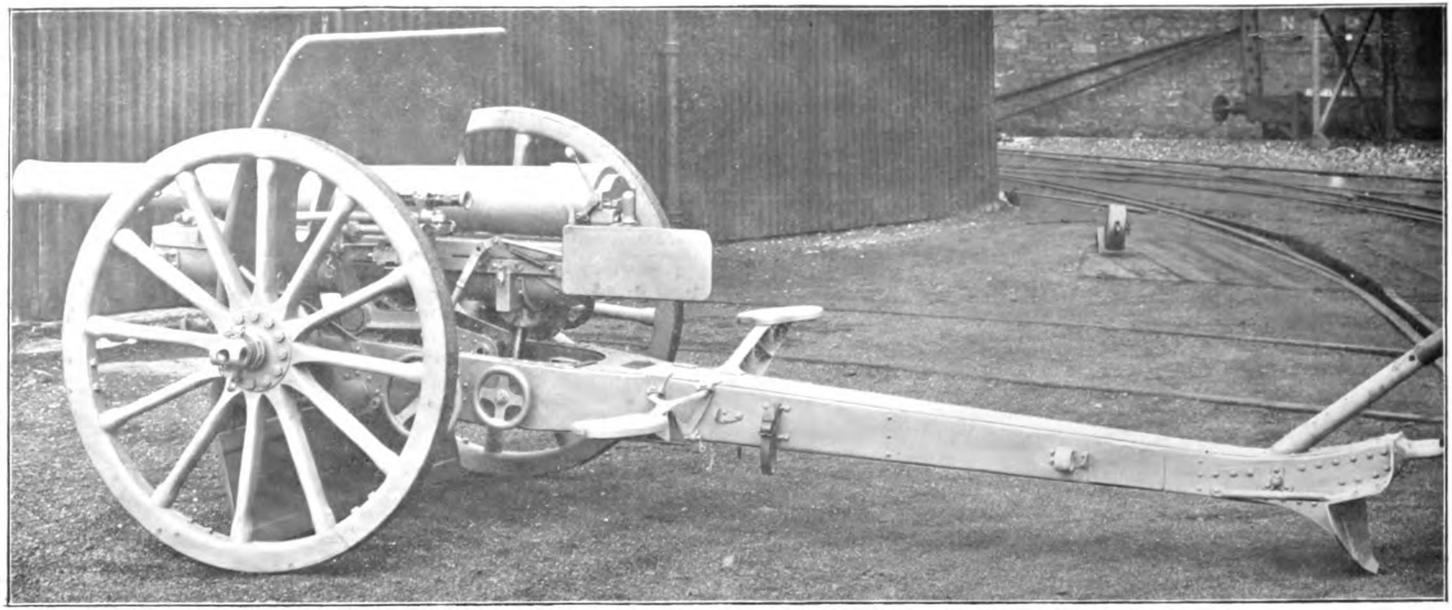
The following conditions have been laid down for the new equipment:

Calibre	2.95 inches
Weight of shell	14.3 lbs.
Muzzle velocity	1640 fs.
Weight behind team ...	31.5 cwt.
Height of wheel... ...	4 ft. 5 ins.

The new gun will probably be a Krupp, very similar to the Italian gun, but somewhat lighter, and with only 24 rounds in the limber.

Peru has purchased two 4-gun batteries from Schneider.

Uruguay has an old semi-quick-firer recoiling on curved guides on the du Bange and Piffard system. Trials, in which Krupp and Schneider are taking part, are now proceeding.



THE ARMSTRONG NAVAL LANDING GUN.

1910.

HORSE ARTILLERY GUNS.

Most nations consider that the difficulty of supplying two different natures of ammunition on the battlefield is a bar to the introduction of a special Horse Artillery gun. Accordingly the H.A. gun is usually the same as the field gun, lightened by removing the axletree seats and using a special light limber containing only about 24 rounds.

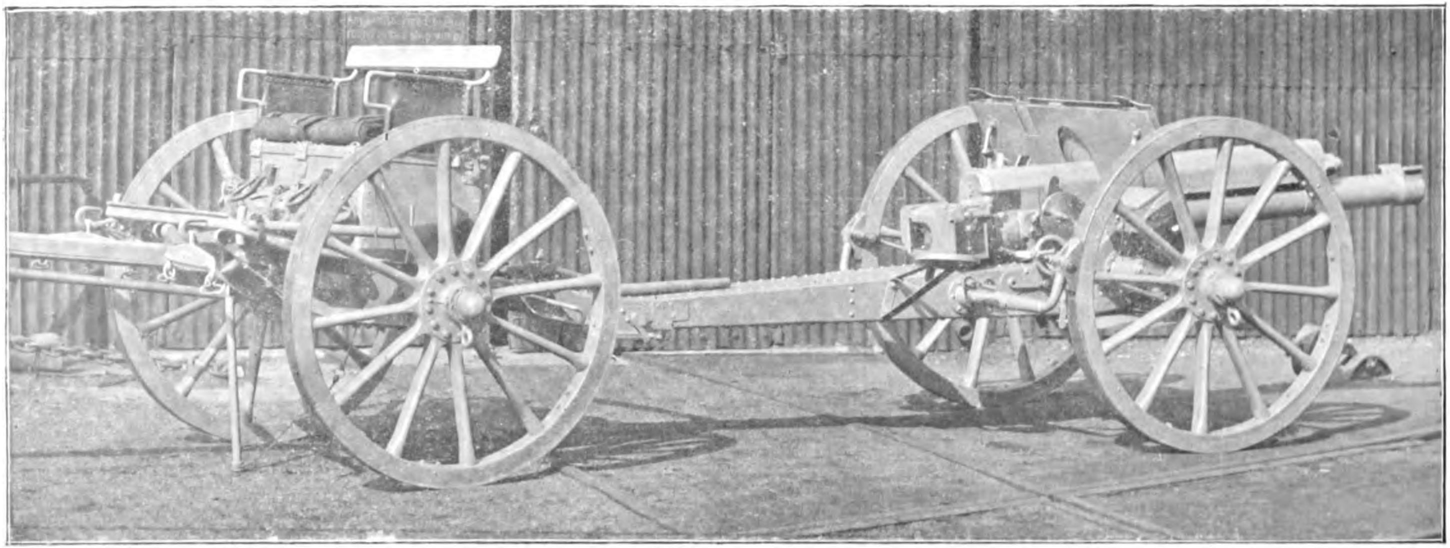
In France attempts have been made to lighten the 75 mm. field gun for use with the cavalry by removing the special brake-shoes under the wheels and the gear connected with them, and one Cavalry Division has been equipped with these lightened guns. But the result is considered far from satisfactory, and a lighter gun is desired. Accordingly the French have been trying a 70 mm. (2.76") H.A. gun on the same system as the F.A. gun, but requiring no *abatage*. It is considered that the weight should not exceed 1500 kilos. (29.5 cwt.) behind the team, without gunners; this, with a light limber, leaves about 18 cwt. for the gun, which will be a light 13 pr. It is to fire only one kind of projectile, namely a combined H.E. and shrapnel shell.

But in view of the reduction of the Horse Artillery, (page 275) the French have for the present postponed the introduction of a new H.A. gun.

Q.F. FIELD GUNS BY VARIOUS MAKERS. 1910.

	Armstrong.			Bethlehem.	Cockerill.	Coventry.	Ehrhardt.		Krupp.		Montlugon.	Schneider.	Skoda.	St. Chamond.	Vickers Maxim, 1910.
	I.	II.	III.				I.	II.	I.	II.					
Calibre, inches	3	2·95	3	3	2·95	3	2·95	3·04	3	2·76	2·95	2·95	2·95	2·95	2·95
Weight of shell, pounds...	13·2	12·5	14·3	15	14·3	15	14·3	14	14·3	14	16	14·3	14·3	14·3	14·3
Muzzle velocity, f.s.	1640	1470	1700	1700	1640	1800	1640	2000	1800	2000	1780	1640	1640	1640	1660
Length of gun, calibres...	28	24	30	28·3	30	30	31		30	35	30	31·4	30	30	35
Breech action	E.S.	E.S.	W	S.B.	E.S.	S.B.	W		W.		E.S.	S.B.	W.	S.B.	S.B.
Line of sight, whether independent ...	Yes.	Yes.	Yes.	No.	No.	Yes.	No.	Yes.	Yes.		Yes.	Yes.	No.	Yes.	Yes.
Springs or compressed air	S.	S.	A.	S.	S.	S.	S.		S.		A.	A.	S.	S.	A.
Traverse on axletree or pivot	P.	P.	A.	P.	P.	P.	P.		P.		A.	A.	P.	A.	P.
Height of wheels	4′ 3″	3′ 6″	4′ 3″	4′	4′ 4″	4′ 3″	4′ 3″		4′ 3″		4′ 8″	4′ 4″	3′ 11″	4′ 3″	4′ 7″
Weight in action with 4 mm. shield, cwt. ...	16·75	12	22·5	19	20	21	19·85	21·75	21	22	19	20	20	20·8	21·5
Number of rounds in limber	39	—	32	36	40	40	40	36	32		20	36	40	36	20
Weight limbered up, cwt.	28·5	—	37	33	35	35	34	37	35·5	36·5	33	35·5	36	35·5	32·5

NOTE.—The Armstrong No. II. is a "landing gun." The Krupp 14-pr. fires a combined shrapnel and H.E. shell.



THE ARMSTRONG 14.3 pr. Q.F. GUN.
WITH COMPRESSED AIR RUNNING-UP GEAR.
1910.

CHAPTER XXXIII.

Q.F. FIELD GUN EQUIPMENTS BY VARIOUS MAKERS.

Armstrong.

(The Elswick Ordnance Company, Newcastle-on-Tyne.)

(See Plate.)

This firm have always taken the lead in England in the manufacture of field guns. After the trials in Greece and the Argentine, in which they competed against the Schneider guns, they have become converts to the hydro-pneumatic axle-traversing system, and have been the first English firm to bring out an equipment of this type.

Their 1910 equipment is a 14.3 pr., M.V. 1700 fs., with compressed air running-up gear. This gun is absolutely steady in action, and is remarkable for the great accuracy obtained. Thus at 6000 metres the mean error in range is only 7.87 metres.

The gun is of 3 inch calibre, of wire-wound construction, and is 30 calibres long. The breech action is the single-motion wedge, with a hang-fire bolt which prevents the breech from being opened until the gun has recoiled, unless the bolt be first withdrawn. It has the independent line of sight, and is sighted with ordinary and panorama sights.

The recoil gear is over the gun, which enables the weight to be kept low. It consists of a hydraulic buffer of the ordinary Elswick construction, and a separate running up cylinder filled with liquid, which is forced on recoil into a cylindrical reservoir filled partly with liquid and partly with compressed air, which surrounds the buffer and running up cylinder. The connecting channel is so arranged that the compressed air cannot obtain access to the gland in any position of the gun.

The gun traverses on the axletree, thus avoiding the complications of a pivoted upper carriage. Experience with the numerous axle-traversing equipments now in use on the Continent has proved that this system is fully serviceable, while it gives a strong and simple construction.

The gun is efficiently shielded; the upper portion of the shield can be inclined back to give overhead cover.

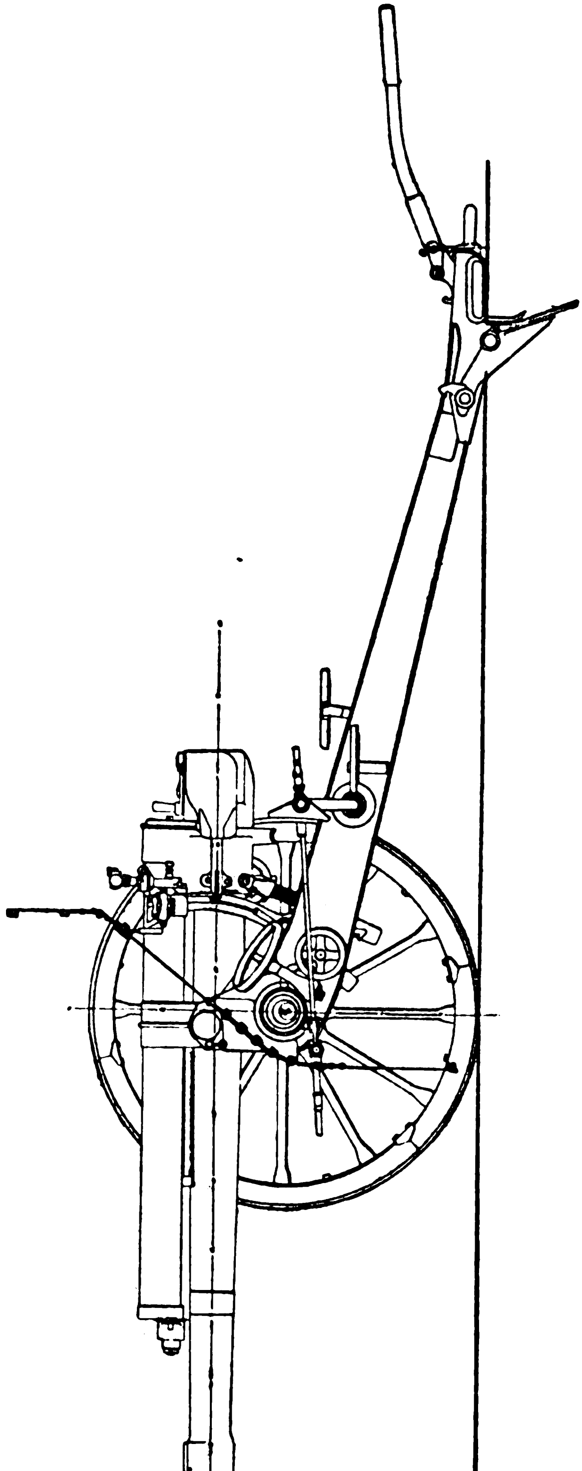
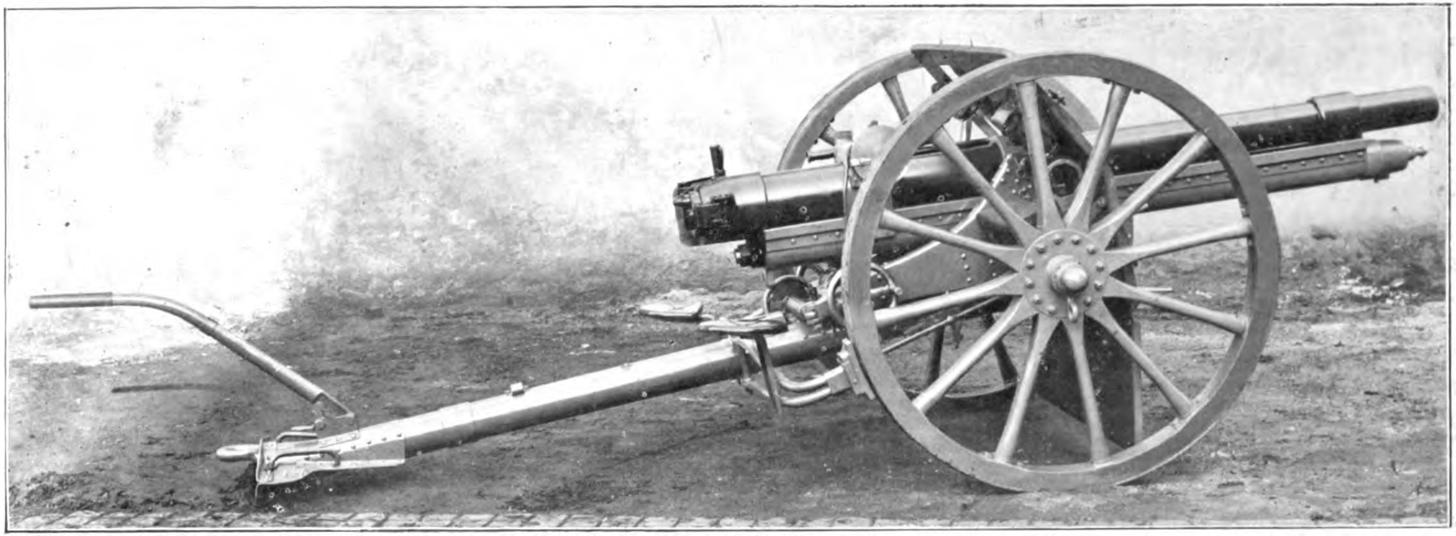


FIG. 122.
THE ARMSTRONG 14.3 pr. Q.F. GUN,
WITH COMPRESSED AIR RUNNING-UP GEAR.
1910.



THE VICKERS MAXIM 14.3 FIELD GUN
WITH COMPRESSED AIR RUNNING-UP GEAR.
1910.

The weight in action with shield is 22.5 cwt. This is slightly higher than that of most 14.3 pr. equipments. But the makers have avoided cutting down weights to a minimum, and have preferred to make every part of the carriage so stout as to give perfect steadiness and freedom from vibration, which is essential to accurate shooting. Now that batteries are protected by shrapnel-proof shields, the value of an accurate weapon, which will make a direct hit on an enemy's gun at 3000 yards almost at every shot, cannot be over-estimated.

The Elswick firm have also a 13.2 pr. equipment suitable for Horse Artillery, or for countries where heavy horses are not available.

This equipment is remarkable for its extreme lightness, the gun weighing only 15.75 cwt. in action without shield. It has a top buffer and telescopic spring-case. The gun is light and comparatively short (28 calibres); the muzzle velocity is obtained by using a large cordite charge, which the wire-wound gun is easily able to withstand. The breech action is the Nordenfeldt eccentric screw. The gun has the independent line of sight and is sighted both for direct and for all-round laying. The elevating gear is the E.O.C. double-ended screw already noticed in the description ot the 18 pr. Q.F. gun.

The wagon and limber are shielded and are intended to be placed beside the gun in action. Fixed ammunition of the ordinary type is used, and each round is carried in a separate tube.

The E.O.C. have recently brought out a "landing gun." The peculiarity of this equipment is that it is divisible into loads not exceeding 200 kilos (440 lbs.) so that it can be easily handled on board ships and can be landed in a boat. It can be quickly put together on shore, and is then a very powerful little gun.

Further details of the above equipments are given in the Table.

VICKERS MAXIM.

(Messrs. Vickers Sons and Maxim, Sheffield.)

This firm have a new 75 mm. 14.3 pr. equipment, M.V. 1660 fs., with compressed air running-up gear. The gun, which is 35 calibres long, recoils on a cradle containing the buffer and compressed air gear. The cradle is mounted on an upper carriage, traversing on a vertical pivot. The gun has the independent line of sight; the elevating gear is a telescopic screw of which the upper portion is rotated for giving elevation to the gun, while the lower portion is raised or lowered, together with the gun and the sights, by rotating a nut on the upper carriage through which it passes. The panorama sight is on a pedestal which can be raised to clear the shield. The breech action is the single-motion interrupted screw.

The recoil gear consists of :—

(a). The hydraulic buffer is of the Vickers' pattern with piston in 3 parts. The liquid has to pass through ports in the piston. The area of these ports is controlled by revolving the piston, by means of rifled grooves in the buffer, so as to secure uniform stability during recoil and a smooth run-up at all elevations. There is no external transmission gear as in guns with variable recoil, and the whole of the gear is simple and compact.

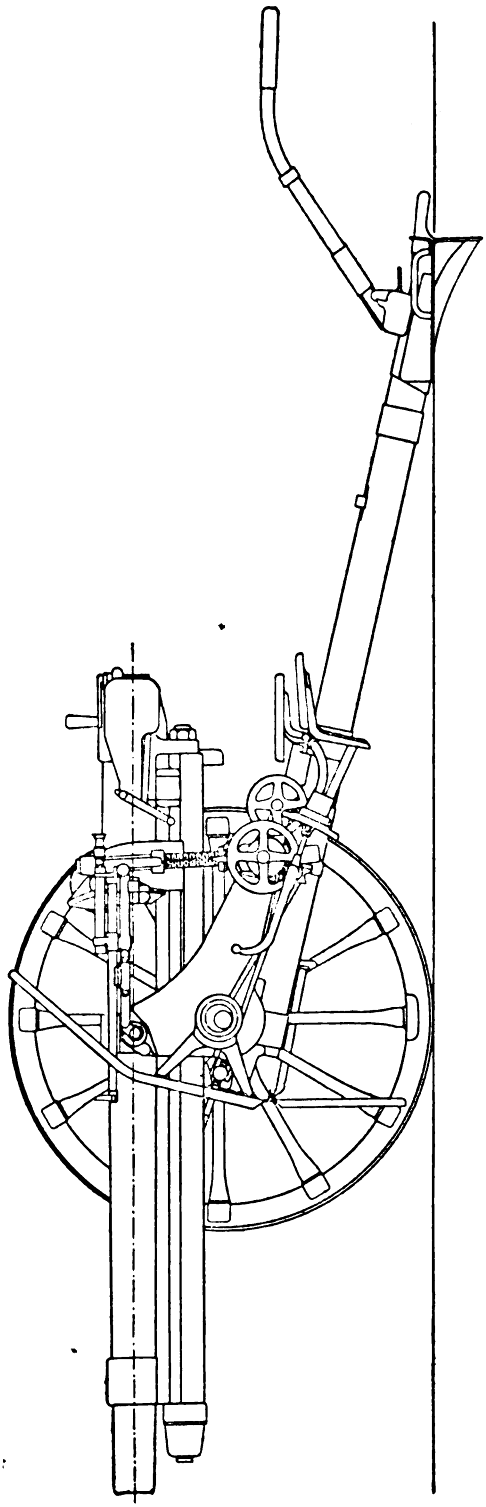
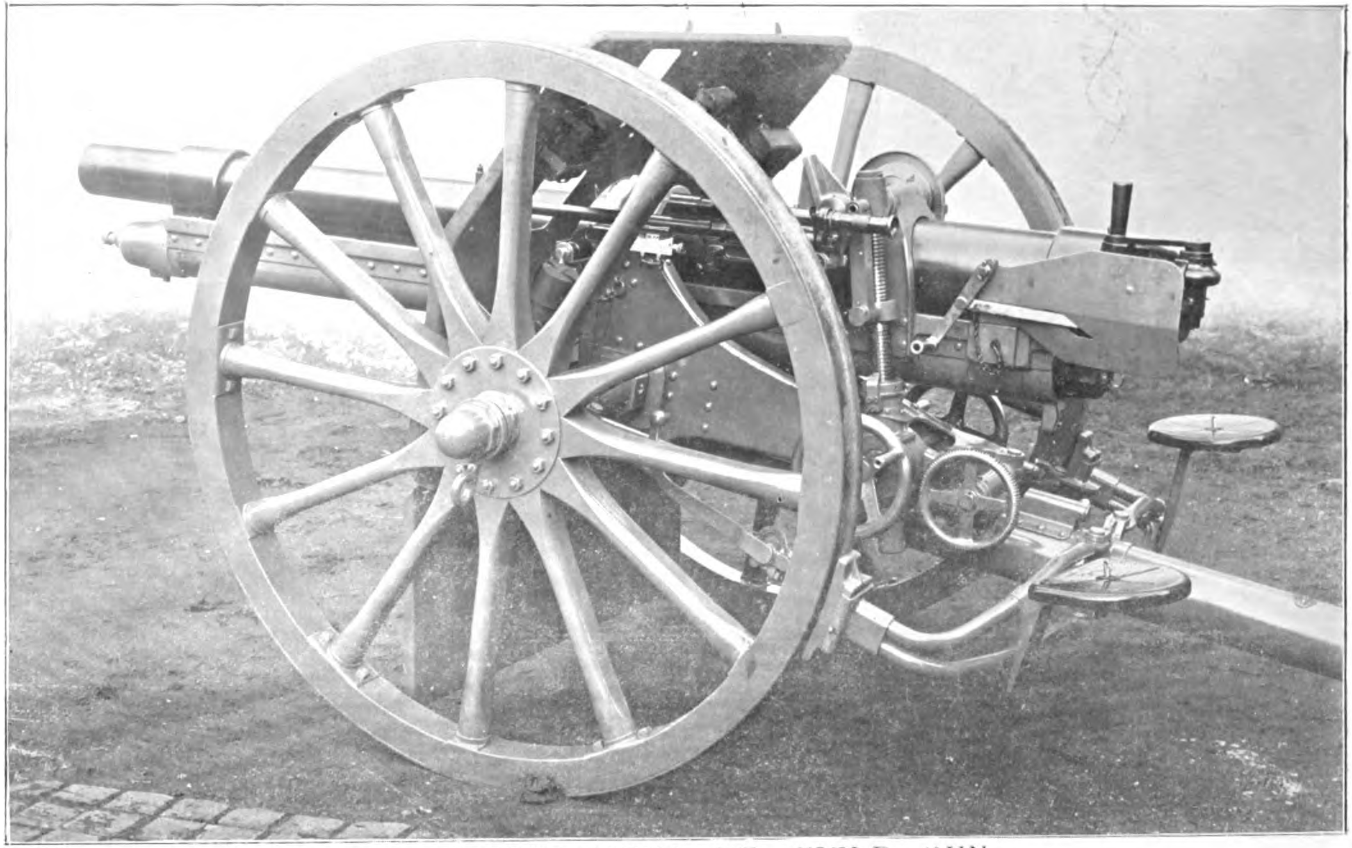


Fig. 123.

THE VICKERS MAXIM 75 mm. Q.F. GUN,

With Compressed Air Running-Up Gear.

1910.



THE VICKERS-MAXIM Q.F. FIELD GUN.

WITH COMPRESSED AIR RUNNING-UP GEAR.

1910.

(b). The running-up cylinder is filled with liquid; it is fixed to the gun, and, on recoil, is drawn off from the piston, which is attached to the cradle, forcing the liquid into the reservoir of compressed air. On completion of recoil the liquid is forced back into the cylinder by the expansion of the air, thus running the gun up. The reservoir is cylindrical and is in rear of and in prolongation of the running-up cylinder; this gives a very neat construction. To prevent the liquid from mixing with the air, a loose or "floating" piston is fitted, an arrangement which has given very good results in the French service gun.

The whole of the gear, except the buffer-piston and running-up piston, recoils with the gun, thus increasing the recoiling weight. The result is that the gun is absolutely steady in action, even at angles of depression.

With 4 feet 7 inch wheels, the gun, with shield, weighs only 21.5 cwt. in action. With 4 feet 3 inch wheels, as in use on the Continent, the weight would be about 1 ton.

COVENTRY.

(The Coventry Ordnance Works, Coventry, England.)

This is a comparatively new firm, and none of their equipments have yet been exhibited on the Continent.

Their standard field gun fires a shell of 6.8 kilo (15 lbs.) with M.V, of 550 m/sec. (1800 fs.), and muzzle energy nearly equal to that of the French service gun. In spite of its power and flat trajectory, the gun weighs only 21 cwt. in action with shield. It has the independent line of sight, with sights automatically corrected for drift and capable of being levelled to compensate for difference of level of wheels. The breech action is similar to that of the 18 pr., and the general construction of the carriage is much the same as in the latest Krupp models. Altogether the gun would appear to be an improvement on the Krupp 7.62 cm. pattern, firing a heavier shell with the same muzzle velocity and the same weight in action.

The Coventry howitzer and mountain equipments are described in Chapter XXXIV and XXXV.

SCHNEIDER.

(Schneider, Canet, et Cie., Le Creusôt, France.)

This firm have long been well known as makers of heavy guns, and in the last few years they have come to the front as makers of field guns with compressed air running-up gear. These have been successful in several recent competitive trials.

Unlike the German makers, Messrs. Schneider have now only one pattern of field gun*. This is a 14.3 pr., 31.4 calibres long, with M.V. of 1640 fs., weighing about 20 cwt. in action. It is rifled with uniform twist, and has a breech action very similar to that of the

*The spring equipment made for Bulgaria was specially demanded, and the Bulgarians have since ordered compressed air gear for their howitzers and mountain guns.

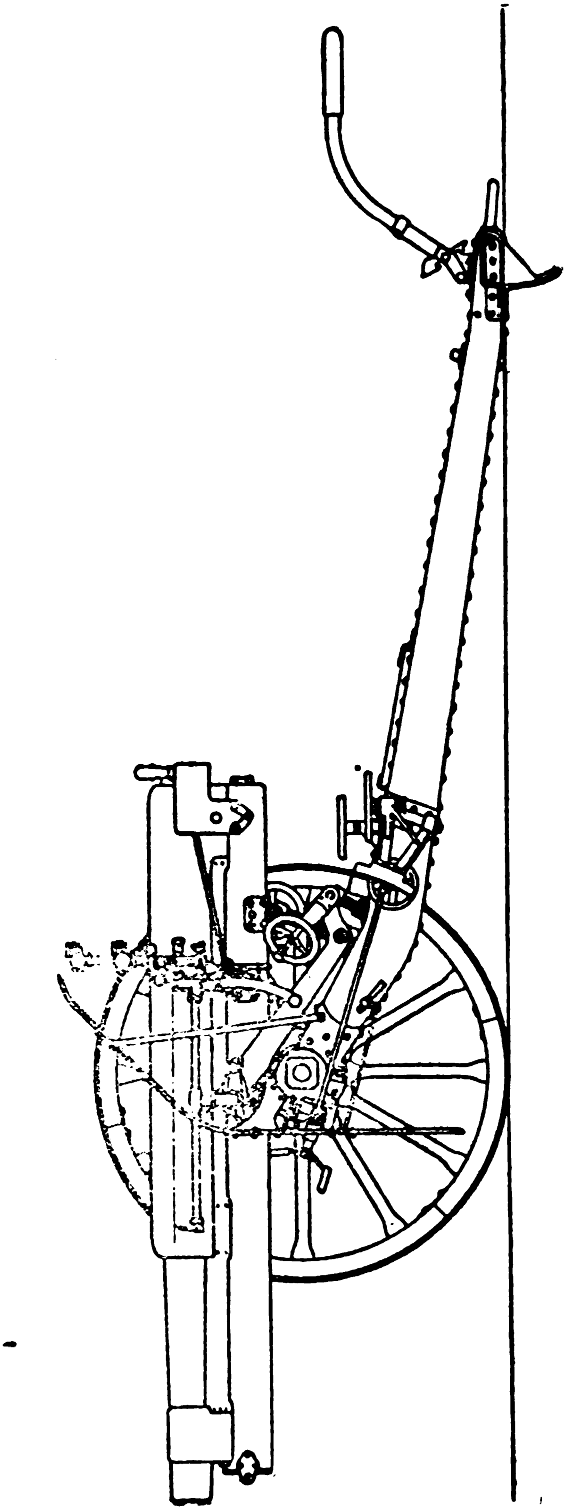
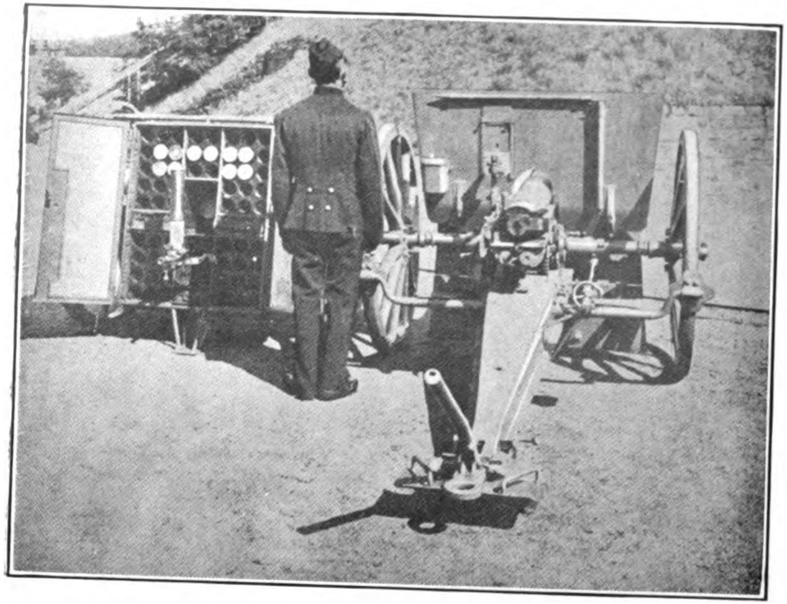
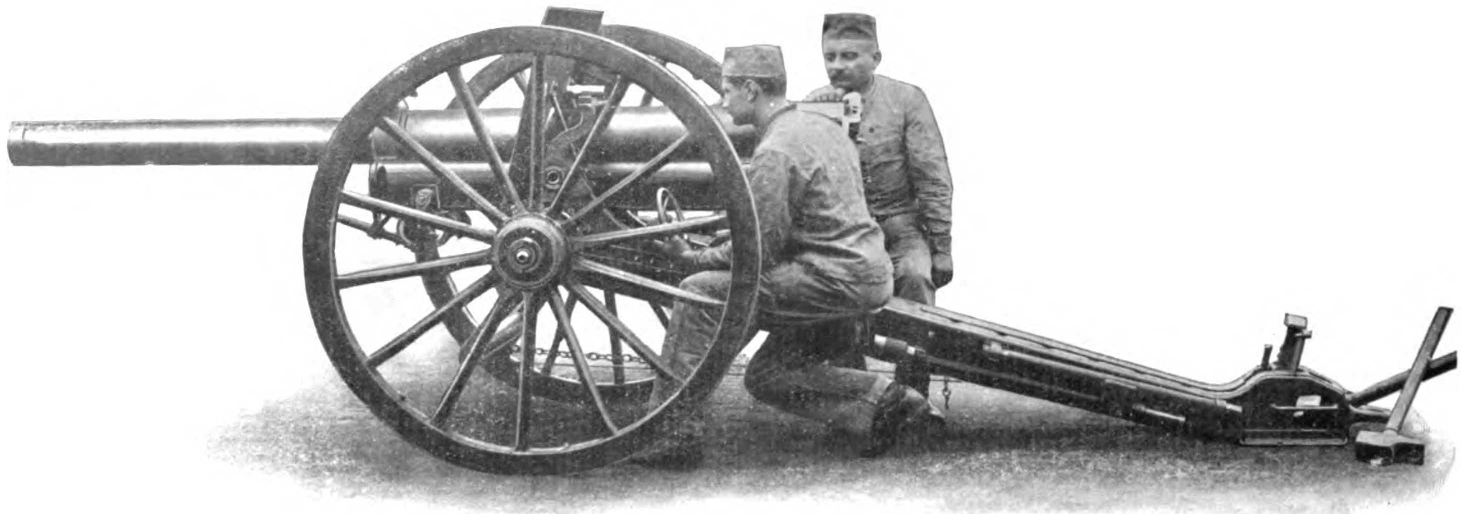


FIG. 124.
THE COVENTRY ORDNANCE WORKS
HIGH-VELOCITY Q.F. GUN.
1910.



THE PORTUGUESE Q.F. GUN.

SCHNEIDER, 1905.



THE DEPORT Q.F. GUN.
1909.

18 pr. The firing gear is a Schneider speciality. The axial striker projects into a recess in the rear face of the breech screw. The firing lever actuates a swinging hammer hanging from the rear end of the cradle, so that it flies up against the projecting end of the striker. Before the hammer can touch the striker, the stem of the hammer must enter a radial recess in the rear face of the breech block; unless the breech block is closed and locked, the recess is not opposite the the stem of the hammer, and the gun cannot be fired. This mechanism is remarkably simple and efficient.

The hydraulic buffer is similar to that of the Russian gun (page 290.) The running-up cylinder (page 124) is entirely independent of the buffer; it contains glycerine, which on recoil is forced into the compressed air reservoir. On completion of recoil the compressed air forces the glycerine back again, and so runs the gun up. The air-pressure before firing is 24 atmospheres.

The buffer, running-up cylinder, and the two compressed air reservoirs all recoil with the gun. These are not separate cylinders, but are holes bored in a crescent-shaped forging which is fixed to the gun, increasing the recoiling weight to 8.4 cwt. This forging is only one-third the height of the ordinary buffer and spring column, and enables the cradle to be made much shallower than usual, getting the gun well down on the axletree. The cradle is much shorter than in spring equipments, being little longer than the recoil-stroke. To support the gun in the extreme recoil position there are two projections below the muzzle, as in the French gun; these engage under the overhanging edges of the cradle guides.

All the Schneider guns traverse on the axletree. The traversing gear is simple and efficient; it consists of an endless screw on the carriage engaging with a rack on the axletree.

The Schneider guns have the independent line of sight. The dial sight, with *collimateur* or panorama telescope, is not on top of the arc sight as in the German equipments, It is on a separate pedestal as in the French service gun, mounted on a bar actuated by the laying wheel, independently of the elevating wheel. This gear is illustrated on page 274. The pedestal has an extension bar which enables the dial sight to be raised above the top of the shield; with the panorama telescope this is not required.

The shield has no folding top; it extends 6 inches above the top of the wheels, which are 4′ 4½″ in diameter. It traverses with the gun, leaving an unprotected space 6 inches wide on either side.

The wagons are of the pattern seen in the Plates. The fuze-setting machine is on the wagon body; it is of very simple construction, without corrector.

Messrs. Schneider now fit spring draught loops and either spring limber hook or spring trail eye to all their carriages.

Further details are given in the Table (page 313) under the heading of the Greek gun.

MONTLUÇON.

(Compagnie des Forges de Châtillon, Montluçon, Allier, France.)

This firm have recently attracted attention as manufacturers of field guns, by the gun shown by them at the Franco-British exhibition

of 1908. This gun, the latest pattern of which is illustrated in the Plate annexed, is the invention of Colonel Deport, the principal designer of the French service gun. It is remarkable for its lightness with respect to its power. Although the wheels are 4 feet 8 inches in diameter, and the gun fires a 16 lb. shell with M.V. of 1730 fs., it weighs, with shield, 19.5 cwt.; when limbered up, with 20 rounds in the limber, it weighs only 30 cwt. behind the team. This remarkable result is attained by the use of the Deport compressed-air buffer described on page 135.

The gun itself is of ordinary construction, except that the recoil guides are above and below the gun instead of at the sides. It is considered that this reduces the vertical vibration of the muzzle and conduces to accurate shooting. The breech action is the eccentric screw (page 101) with semi-automatic action (page 103). The gun traverses on the axletree, and has the independent line of sight, with ordinary and panorama sights.

Instead of a spade, there is a strong serrated spike at the end of the trail, which is driven into the ground with a hammer. This is said to answer well, and to prevent any forward motion of the gun during the run-up. It is however doubtful whether the spike would answer well on soft ground, and the swallow-tail spade shown in the Plate of the earlier pattern (Chapter XV) would appear preferable.

The semi-automatic breech action appreciably increases the rate of fire, since there is no delay in closing the breech. But, in guns with the independent line of sight, it does not save a man at the gun, since there has to be a gunner at the right of the breech in order to look after the elevation.

The Montluçon firm are now bringing out their 1910 field gun. This is of the same power as the gun already described, but is even lighter. It has the differential recoil gear described under the heading of the Deport mountain gun (Chapter XXXV.) This enables the recoil to be shortened so that the gun can be fired at angles of elevation up to 75°, enabling it to be used as a howitzer or as a balloon gun. The details of this equipment have not yet appeared.

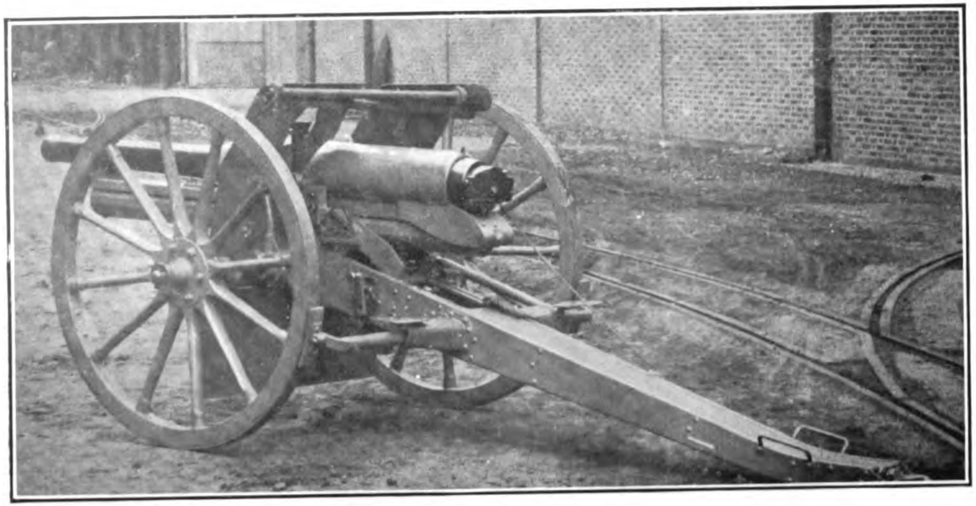
ST. CHAMOND.

(Compagnie des Forges d'Homécourt, St. Chamond, Loire.)

(See Plate.)

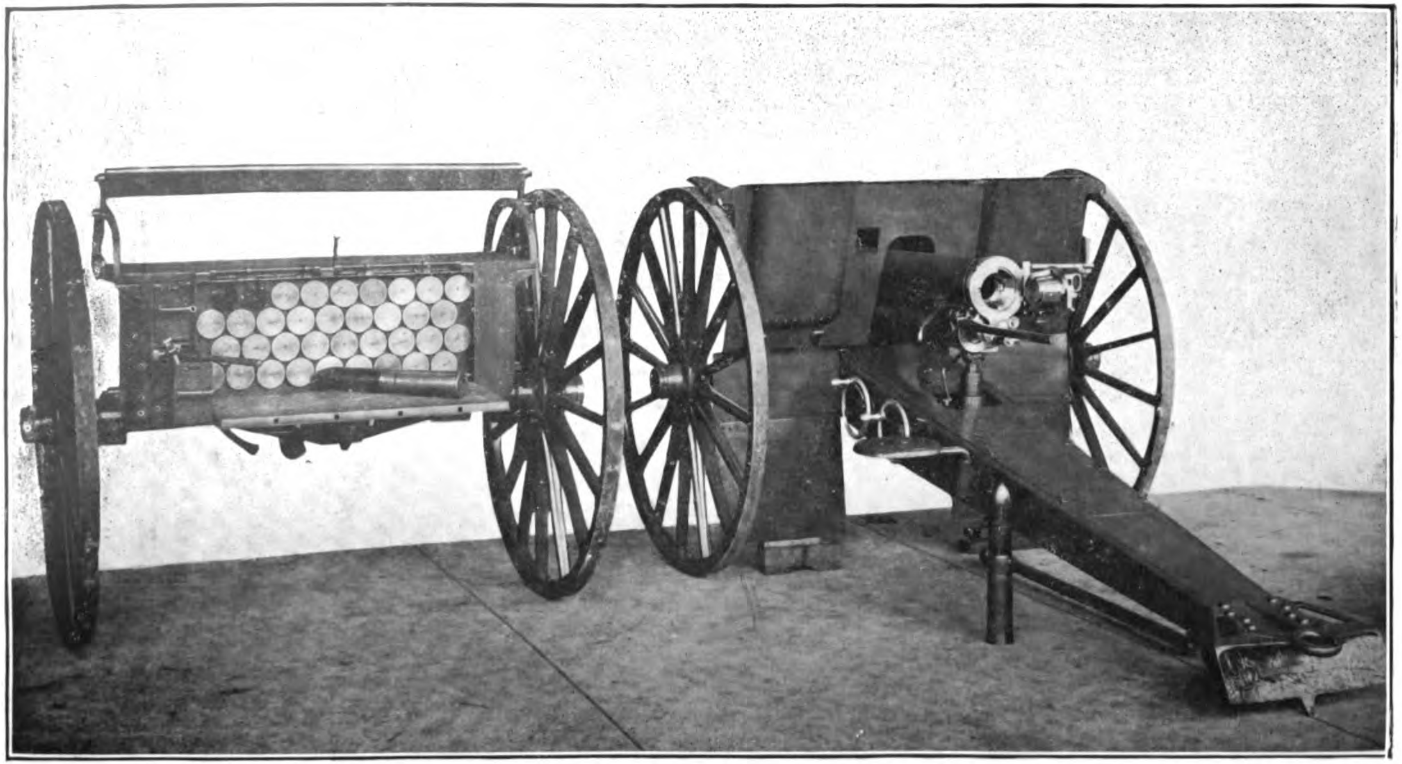
The standard gun made by this firm is a 75 mm. 14.3 pounder, M.V. 1640 fs.

The gun is of special steel, 30 calibres long. It has an interrupted screw breech-block with repeating trip-lock. It is sighted on the cradle with a panorama sight, and has the independent line of sight. The gun is mounted on a sleigh of which the transverse section is the arc of a circle. This sleigh rides on the cylindrical cradle. The cradle contains the buffer and single column of springs. The buffer recoils with the gun; it is of the ordinary construction, with check-buffer. The gun traverses on the axletree; it requires no *abatage*.



THE MEXICAN Q.F. GUN.

ST. CHAMOND, 1902.



THE BETHLEHEM 3″ Q.F. GUN.

1906.

The limber and wagon are remarkable in that all the ammunition boxes are on springs, and that spring draught-loops and spring limber-hooks are fitted. The (fixed) ammunition is carried vertically. The wagon body is tipped beside the gun in action, and has an automatic fuze-setting machine.

The gun fires 25 rounds a minute, and the sights and elevating and traversing gear are specially designed for fire from behind cover and for searching and sweeping. Both gun and wagon are fully shielded.

For further details, see the Mexican gun.

BETHLEHEM.

(The Bethlehem Steel Company, Pennsylvania, U.S.A,)

(See Plate.)

This firm makes a speciality of powerful field guns. Their No. 6 (No. 1 in the Table) is a 3″ gun firing a shell of 15 lbs, M.V. 1700 fs. The makers claim that with 5-millimetre shield it weighs only 19 cwt. in action. Steadiness is ensured by using wheels only 4 feet in diameter.

The gun is 89 inches long, and weighs 6.75 cwt. It has a conical interrupted involute screw breech-block on the Bethlehem system, giving a locking surface extending over 240 degrees of the circle. It has a self-cocking percussion lock, not a trip-lock.

The recoil gear is a Bethlehem speciality. There are twin hydraulic buffers under the gun, with the running-up springs inside the buffers. These buffers are nearly as long as the gun. Taking the effective length of the buffers at 80″, this means that the springs are compressed from a length of 80″ to a length of 35″ on recoil. This degree of compression is moderate for good springs.

Several practical advantages are gained by putting the springs inside the buffers. The springs require no parting-plates; they are well lubricated and always work smoothly; and working them in oil instead of in air reduces the vibration and consequently the liability to fracture.

The cradle traverses on a vertical pivot set in a socket which is fixed to a sleeve surrounding the axletree, so that the axletree, although it forms the horizontal pivot, does not turn when the gun is elevated.

The trail is of box pattern with a spade inclined at a sharp angle. The elevating gear is of the double screw type. The straight axletree is hollow, with the arms screwed in. The brake-bar is on the muzzle side of the wheels. The gun has ordinary and panorama sights, and is fully shielded.

The Bethlehem gun limbers, wagon limbers, and wagon bodies are all interchangeable. The wagon body has a limber-hook in rear, and the perch is removable so that a pole can be inserted instead. All the ammunitions boxes are removable, and any limber can be made into a wagon body by placing a second ammunition box on top of the first, the stancheons fitting into the guard-iron sockets. This interchangeability of equipment is a great advantage.

The Bethlehem No. 5 equipment (No. II in the Table) differs from the last-described in that it is a controlled-recoil equipment. The length of recoil is automatically reduced from 60" to 50" as the elevation is increased. This gun has a single buffer with twin spring-columns on either side of it.

COCKERILL.

(Messrs. John Cockerill, Seraing, Belgium.)

(See Plate.)

The standard field gun made by this firm is a 14.3 pounder, M.V. 1640 fs. It differs in several respects from the ordinary construction.

Between the gun and the cradle is a sleigh; the gun slides on the sleigh, and the sleigh on the cradle. There is a tension spring between the gun and sleigh, and a compression spring between the sleigh and the cradle. Since the sleigh only recoils for half the distance that the gun recoils, this arrangement serves the same purpose as the telescopic spring-case. It is claimed for these tension springs that it is practically impossible to break them. The sleigh also serves the purpose of supporting the gun in the extreme position of recoil, and thus enables the cradle to be kept much shorter than usual, saving about 1 cwt. of weight.

The recoil and run-up are regulated at all angles of elevation by a stop-cock which automatically constricts the channel through which the buffer-liquid flows. This gear is described in the chapter on Controlled Recoil.

The Cockerill 1905 gun has not the independent line of sight. The makers object to this as it renders it impossible to correct the sight for difference of level of wheels. (This does not apply to the Krupp sight illustrated on page 93, nor to Col. Scott's "Automatic line of sight.") They therefore prefer an arc sight of which the socket is pivoted parallel to the axis of the piece, on Col. Scott's reciprocating system, so that it can be cross-levelled for all-round laying. A panorama telescope is mounted on the arc sight.

Another peculiarity of the Cockerill gun is the care taken to protect the working parts both from the enemy's fire and from dirt. Note in the Plate the bellows casing round the elevating screw.

The gun is efficiently shielded. The shield is set far back, and the upper part can be sloped back to give overhead protection to the gunners.

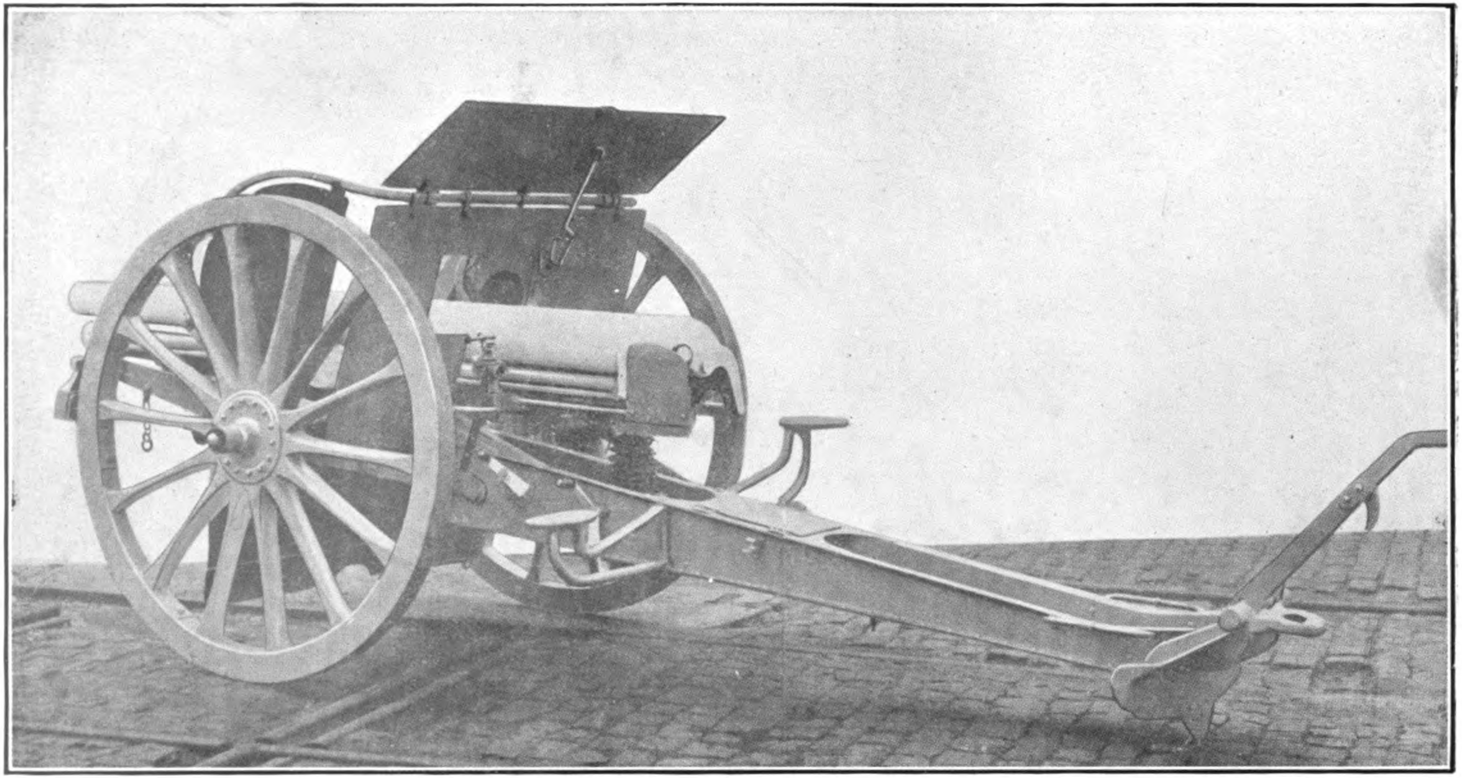
The breech action is the eccentric screw.

KRUPP.

(Messrs. F. Krupp, Essen, Rhenish Prussia.)

The equipments made by this famous firm are so widely known as to need little description. The following points may be noted:

Messrs. Krupp make 4 different types of field gun, namely a 13.2 pr. weighing 18 cwt. in action; a 14.3 pr., M.V. 1640 fs., weighing 19.5 cwt.; a 14.3 pr., M.V. 1800 fs., weighing 21 cwt., and a high-



THE COCKERILL 75mm. Q.F. GUN.

1905.

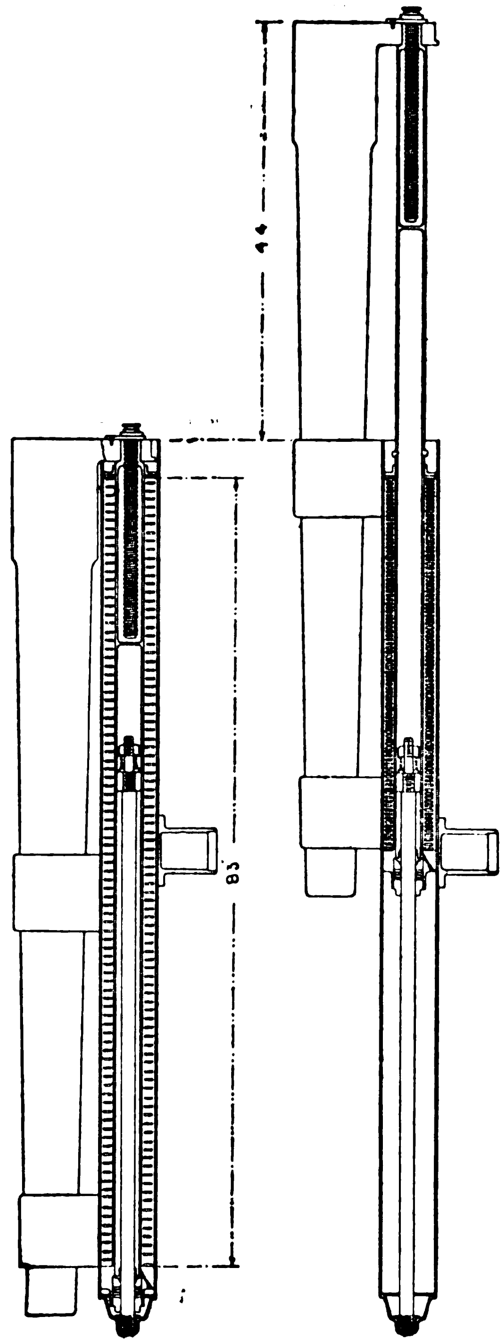


FIG. 125.

DETAIL OF KRUPP BUFFER AND SPRINGS.

velocity 14 pr. weighing 22 cwt. Any of these can be fitted with either semi-automatic or fully-automatic wedge breech mechanism.

These equipments have the following points in common ;

The cradle, containing the buffer and springs (Fig. 125) is of rectangular shape and is under the gun. It pivots on a vertical trunnion in a saddle, which is supported on cross trunnions between the trail brackets ; these trunnions are inclined to compensate for drift. The saddle is prolonged to the rear to form the traversing bed. The hydraulic buffer is attached to the gun by a screw (Fig. 125) which also serves to put the initial compression on the springs.

Messrs. Krupp make two patterns of buffer. In one, the run-up is controlled by a Vavasseur valve, as described on page 129. But in their latest constructions Messrs. Krupp have reverted to the check-buffer.

The check-buffer plunger has an axial channel through which the glycerine flows into the hollow piston rod during recoil ; during the run-up this channel is closed by a valve inside the enlarged breech end of the plunger, which shuts under the pressure of the liquid : the glycerine in the hollow of the piston rod has then to escape down the outside of the plunger, through ports formed in its outer surface. The valve is necessary, since otherwise a vacuum would be formed in the hollow piston rod during recoil, and the gun would run-up with a jerk. Theoretically, this check-buffer construction affords less perfect control of the run-up than the Vavasseur valve ; it is however simpler, and Messrs. Krupp by long experience have been able to adjust the dimensions of the channels through which the liquid has to flow so as to get a very smooth run-up.

The Krupp springs are of well-known excellence. The firm use a single column of springs, in 4 lengths, coiled alternately right and left-handed : there are no parting plates, and the whole column weighs only 44 lbs. The springs are of wire, of flat section with rounded edges.

The Krupp single-motion wedge breech action is very similar to the Ehrhardt wedge illustrated on page 101, and has much the same extractor and repeating trip-lock. A hang-fire bolt is sometimes fitted ; this locks the breech as soon as it is closed, but is disengaged automatically by the recoil. To open the breech before the gun has been fired, the bolt must first be withdrawn.

The later Krupp guns have the independent line of sight, and are fitted with the reciprocating sight illustrated on page 93, with panorama attachment.

The Krupp limbers and wagons are of steel throughout, including the poles. Most nations prefer the tilting pattern of wagon body as shown in Fig. 126. The later Krupp carriages have spring draught and spring limber hooks : the latter are keyless, the trail eye being dropped in and held by a catch. A fuze-setting machine is fitted to the wagon, and an observing ladder is provided if desired.

The Krupp ammunition has already been described.

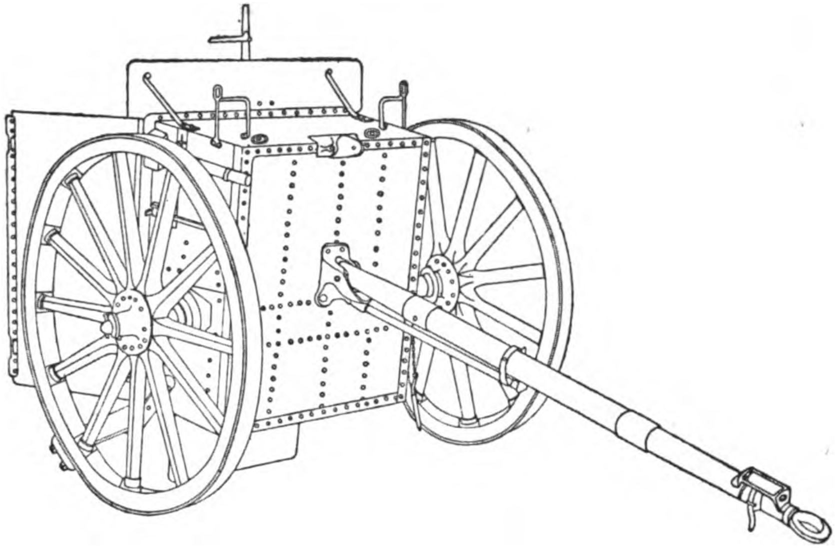


FIG. 126.

KRUPP WAGON BODY.

The best example of the light Krupp equipment is the Argentine 13.2 pr.: the ordinary equipment is represented by the Italian gun. A heavier pattern is the 3-inch gun with M.V. of 1800 fs. Krupp has also a 7 cm. (2.76″) high-velocity gun with M.V. of 2000 fs. This is 35 calibres long, and has the semi-automatic breech action described on page 103. Further details of the two latter equipments are given in the Table.

The Krupp howitzers and mountain guns are dscribed in Chapters XXXIII and XXXIV; the Krupp balloon guns in Chapter XXI.

EHRHARDT.

(The Rheinische Metallwaaren und Maschinenfabrik, Duesseldorf, Rhenish Prussia.)

(FIG. 127.)

This firm was the first to bring out a gun-recoil equipment of the present German pattern. Their earlier guns are similar to the 15 pr. Q.F. gun in our own service, with telescopic trail and cradle pivoted in a socket in the revolving axletree.

In their later equipments the trail is of the form shown in the figure. The cradle is pivoted on horizontal trunnions on an intermediate carriage, which itself traverses on a vertical pivot set in a sleeve on the axletree, which does not revolve. There are twin double-ended elevating arcs. By turning a laying wheel on the intermediate carriage the arcs, gun, and sights are elevated together; by turning an elevating wheel on the cradle the gun moves up or down the arcs without moving the sights. So far the principle is the same as that of the E.O.C. double-ended elevating screw gear. But in the Ehrhardt gear the arcs themselves are utilized as arc sights,

being struck with the cradle-trunnion as centre, and the panorama sight is mounted directly on top of the left-hand arc. The clinometer level is fixed to the side of the same arc.

For direct laying a rocking-bar sight is used as an alternative to the panorama telescope. The rocking-bar is an integral portion of the left-hand arc; it passes through the axis of the cradle trunnions and is continued to the front so as to give a sighting radius of 1 metre. The foresight is capable of lateral movement, and is governed by a cam on the side of the cradle, which moves it to the right as the gun is elevated. This gives the true correction for drift at all angles of elevation.

The latest Ehrhardt gear differs from that just described in that the arcs are single-ended. They are continued downwards only as far as the intermediate carriage, to which they are fixed. The intermediate carriage is elevated and depressed by the laying screw, which is a central screw of the ordinary pattern.

The Ehrhardt wedge breech action is illustrated on page 101. The gun itself is made by the special Ehrhardt process described on page 74; it is of nickel steel, rifled with increasing twist.

Messrs. Ehrhardt are the original inventors of the Ehrhardt-Vavasseur controlled recoil system described in Chapter XV, which is now extensively used for howitzers and mountain guns. But they do not consider it necessary to use this gear in field guns, and their recoil gear, which is remarkably efficient, is much the same as in the later Krupp equipments.

In the original equipment three concentric columns of springs were used, but since the adoption of the running-up valve these have been replaced by a single column of light springs. The initial compression is given to these springs by an inner sleeve with a shoulder against which the springs abut; this sleeve, which is about 2 feet long, is screwed on to the buffer cylinder, which is threaded to receive it, till the necessary compression is obtained. This enables the springs to be quickly removed and replaced.

Messrs. Ehrhardt are very successful makers of ammunition, and claim to get a higher percentage of bullets and driving charge into a field shrapnel than any other firm. They draw their cartridge cases hot. Their shrapnel bodies are made by forcing a plunger into a hot ingot, which is then drawn out by passing it through three successive sets of dies. Another Ehrhardt speciality is their method of rolling in the incurved shoulders of the shrapnel bodies instead of pressing them in.

The Ehrhardt ammunition and fuzes have been described in Chapter XVIII.

The firm turn out light, medium, heavy, and high-velocity equipments: these differ from the Krupp equipments principally in being somewhat lighter.

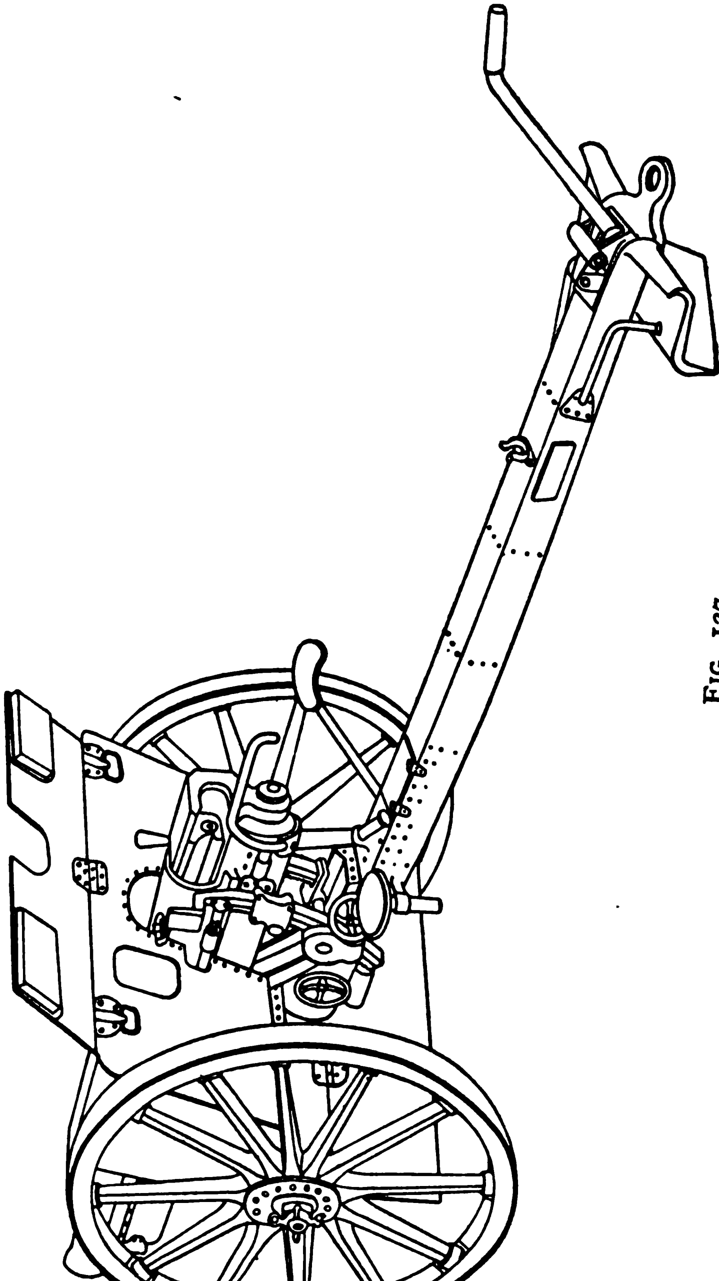


Fig. 127.
EHRHARDT 75 mm. Q.F. GUN.
With Independent Line of Sight.
1906.

SKODA.

(The Skoda Waffenfabrik, Pilsen, Bohemia.)

(See Plates.)

The standard gun made by this firm is a 75 mm. 14.3 pounder, M.V. 1640 fs. The gun is of nickel steel, 30 calibres long.

It is rifled with increasing twist, and has the Skoda single-motion wedge breech. This action is closed and locked by a knuckle-jointed lever, and is a simple and very serviceable gear. It has a repeating trip-lock and firing-lever. The extractor is actuated by a projection on the wedge which strikes a bent lever when the breech is opened.

The gun has an arc sight, which is pivoted so that it can be cross-levelled to correct for difference of level of wheels. It is inclined to correct for drift. The arc sight carries a base-plate and divided circle with sighting telescope for direct or all-round laying. The telescope, which also carries open sights, can be raised above the base-plate by means of a pillar when an extra high line of sight is required. A panorama sight can also be fitted on the base-plate.

The clinometer, which is adjustable for angle of sight, is carried low down on the side of the arc sight.

The cradle is cylindrical, and contains the guides as well as the buffer and springs. A steel forging inside the cradle slides backwards and forwards on these inside guides, and the gun is supported on this by connecting-pieces which pass through a slit in the upper surface of the cradle. The cradle only extends forward to 2/3 of the length of the gun; on the other hand, it projects about one foot in rear of the breech. The object of this is to keep the working parts behind the shield and to support the gun at extreme recoil. The spring case is telescopic. A spare set of springs and spring-case, with the initial compression already on, is carried in the hollow perch of the wagon.

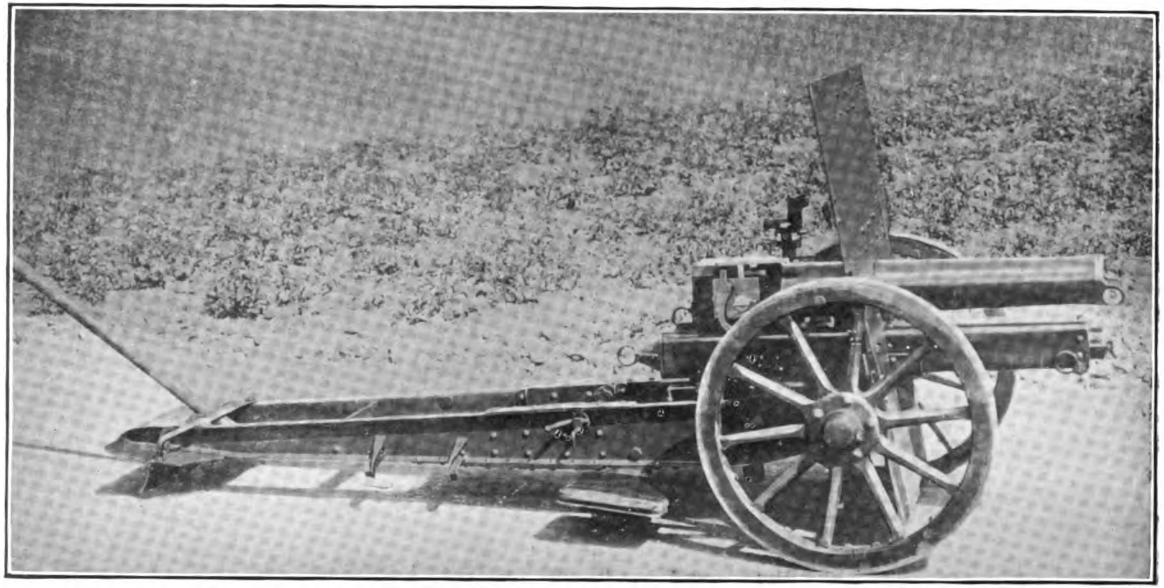
The gun fires fixed ammunition, both shrapnel shell and H.E. shell loaded with ammonal. The ammunition is carried by fours in steel boxes. The wagon body is unlimbered beside the gun in action, but is not tipped; the perch is supported by a prop. The gun and wagon are fully shielded; the gun-shield has a folding top like that of the German guns.

This equipment has unusually low wheels, namely 3′ 11½″.

Some features of this equipment, such as the reciprocating arc sight and the cylindrical cradle projecting to the rear, have been adopted in the 1905 Austrian gun.

The Skoda 1910 equipment is now under trial by the Austrian Government.

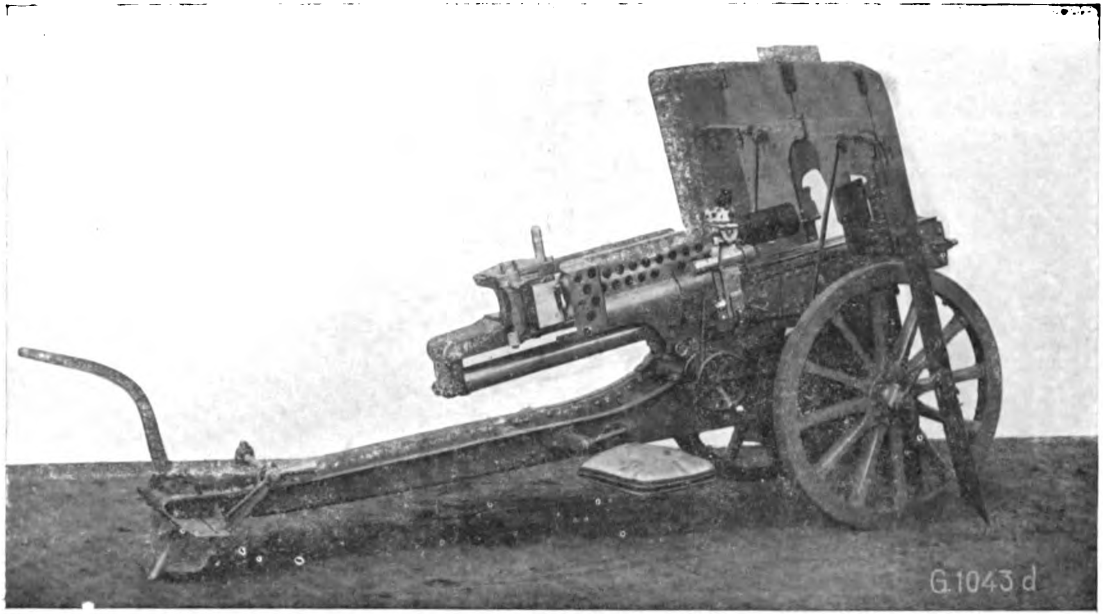
Page 330.—Skoda has recently supplied 18 field guns with 6000 rounds ammunition to China. The gun is a 14.3 pr. similar to that described in the text, but weighs only 18.5 cwt. with 3.5 mm. shield, on 4′ 3″ wheels. The buffer has piston valves and no check-buffer; the gun traverses on the axle, subsidiary shields being fitted to fill the gaps between the main shield and the wheels.



THE SKODA 75mm. Q.F. MOUNTAIN GUN.
1905.

TABLE OF FIELD HOWITZERS. 1910.

	Vickers Maxim, 1909.	Coventry, 1910.	Krupp, light.	Krupp, medium.	Ehrhardt, light.	Ehrhardt, medium.	Cockerill.	Schneider.
Calibre, inches	4·83	4·625	4·2	4·7	4·2	4·7	4·7	4·2
Weight of shell, lbs.	35·27	37·5	31	46	31·5	50	45	35
Muzzle velocity, full charge, f.s. ...	1045	1000	985	985	985	990	985	985
Length, calibres	15	15·5	14	14	13·5	14	12	14
Breech action	S.B.	W.	W.	W.	W.	W.	E.S	S.B.
Rear trunnions or controlled recoil ...	R.T.	C.R.	R.T.	R.T.	C.R.	C.R.	Both.	C.R.
Springs or compressed air	S.	S.	S.	S.	S.	S.	S.	A.
Traverse on axletree or pivot ...	P.	P.	P.	P.	P.	P.	P.	A.
Height of wheels...	4' 8"	4' 8"	4' 3"	4' 8"	3' 11½"	4' 1½"	4' 4"	4'
Weight in action with 3·5 mm. shield, cwt.	27	24·25	20·8	26	21	25	25	21·5
Number of rounds in limber ...	12	12	24	16	18	12	16	16
Weight limbered up	41	38	36·8	42·7	36	41	42	36·5



THE KRUPP DIFFERENTIAL RECOIL MOUNTAIN GUN.

1909.

CHAPTER XXXIV.

Q.F. FIELD HOWITZER EQUIPMENTS.

General.

No Continental nation has yet brought out a Q.F. howitzer of its own. The great Powers are still experimenting, and the minor Powers have purchased howitzers from the leading makers, mostly from Krupp and Schneider. The existing patterns are therefore less numerous than the patterns of field gun.

There are two principal systems of construction, the Krupp and the Ehrhardt; the latter has also been adopted by Schneider. As explained in Chapter XIX, the difficulty in constructing a howitzer carriage is to provide room for the howitzer to recoil at high elevations without striking the ground. This is effected in the Ehrhardt equipments by "controlled recoil" gear, which automatically increases the resistance and shortens the recoil as the howitzer is elevated. This system is described on page 129. The alternative system, adopted by Messrs. Krupp, is to set the cradle trunnions under the breech, or even further to the rear. Thus when the howitzer is elevated the clearance under the breech remains the same, or is even increased, so that there is room for 43 inches of recoil. With this length of recoil, the howitzer is perfectly steady when fired point blank with full charge, which may often be necessary on emergency. In fact the German light field howitzer is always used as a gun unless a special target calling for high-angle fire presents itself.

The advocates of the rival system object to rear trunnions on various grounds. It is stated that the cradle is not firmly supported, causing considerable vibration at the muzzle and consequent inaccuracy. Since the howitzer is not balanced, but has the whole of its weight in front of the trunnions, the resulting heavy strain upon the elevating gear has to be relieved by fitting a balance spring under the fore end of the cradle. When it is fired, the howitzer is resting on this spring which gives causing the muzzle to dip. When the

Page 333.—The new British, German, Austrian and Dutch field howitzers are described in amendment to page 345; the French are trying a 4.2″ and a 4.7″ howitzer, and the Russians a 4.2″ Schneider howitzer, similar to those supplied to Bulgaria, Servia and Greece. The new Belgian field howitzer has semi-rear trunnions and constant long recoil. Sweden has a new Bofors howitzer, on the controlled recoil system, firing a 31 lb. shell with M.V. 985 fs., and weighing 20.6 cwt. in action. Switzerland has a 4.7″ Krupp howitzer, 1912 pattern, with rear trunnions and recoil of 1 metre; 60 of these have been supplied. Turkey has 18 four-gun batteries of Krupp 4.7″ howitzers, 1892 pattern.

Messrs. Krupp claim to have overcome the above difficulties, and certainly their 4.7" howitzer, as supplied to Switzerland and other countries, appears to be a fully serviceable weapon. But these undoubted objections have caused the leading military nations to hesitate before committing themselves to the rear-trunnion system.

The objections to controlled recoil have already been stated on page 131. The only alternative systems are curved or swinging recoil, which is still in the experimental stage, and the Schneider method of revolving a cranked axle so as to raise the howitzer when firing at high elevations. The latter method has been successfully applied in the Schneider mountain howitzers; but the gear would have to be strong and heavy to stand the recoil of a field howitzer. There is also a possibility of employing the differential recoil system (page 133) as in the Krupp balloon gun. This would enable the carriage to be kept steady at all elevations with a constant recoil of some 15 inches; but the practical difficulties in the way of applying differential recoil to a field carriage have yet to be overcome.

Compressed Air Gear.

The weight of the springs required to lift a 9-cwt. howitzer 48 inches at 45° elevation becomes a serious item, and even Krupp, who will have nothing to say to compressed air gear for guns, has brought out a hydro-pneumatic howitzer.

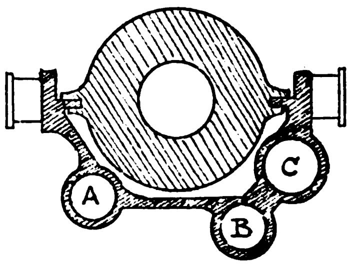
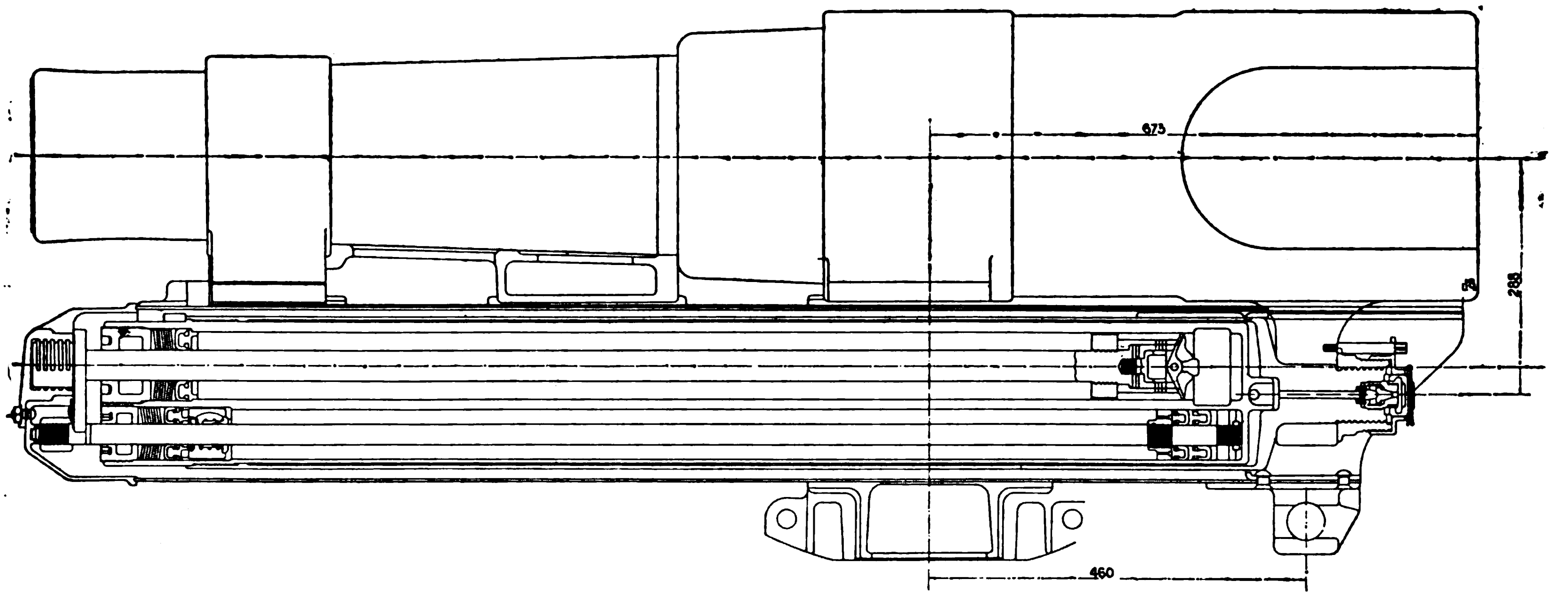


FIG. 128.

DIAGRAM OF SCHNEIDER GEAR.

In the Schneider howitzer gear the buffer, A, running-up cylinder, B, and air reservoir, C, are holes bored in a trough-shaped forging which constitutes the cradle. In the Krupp gear, the buffer and running-up cylinder are both contained within the cylindrical compressed air reservoir, and all three recoil together with the howitzer. The piston rods are attached to the cradle, which is the reverse of the arrangement adopted in the Schneider howitzers. This is a neat arrangement, and has the advantage of increasing the recoiling weight, but the axis of the howitzer is higher than with the Schneider pattern.

In both gears the running-up cylinder is completely filled with glycerine, which also partly fills the air reservoir. The communicating channel is near the centre, and is covered by the liquid both in the firing and in the travelling position. This is shown in the illustration on page 125.



KRUPP COMPRESSED-AIR GEAR FOR HOWITZERS.

FIG. 129.

Figs. 129 and 130 show the Krupp hydro-pneumatic gear. The cylindrical compressed-air reservoir is seen attached to the horn at the breech end of the howitzer. It contains the hydraulic buffer above, and the compressed air running-up cylinder below. These are seen in the rear view, Fig. 130; the third circle is the plug closing the end of the channel which connects the running-up cylinder with

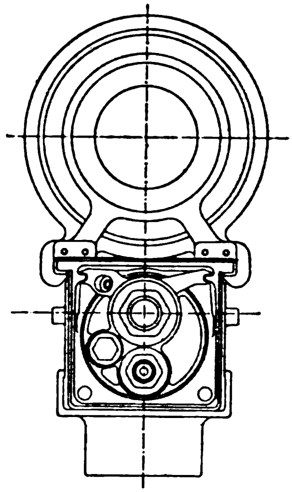


FIG. 130.

the air reservoir. There is no check-buffer; the butterfly-shaped valve which regulates the run-up is seen at the rear end of the buffer piston in Fig. 129. The running-up piston has two U-leathers faced with gun-metal rings; the glands through which the two pistons pass are packed in the same way. The central channel in rear, in line with the axis of the reservoir, serves for pumping in compressed air; the screw plug above it is for filling the buffer, while glycerine is pumped into the running-up cylinder from the front, through the hollow piston rod.

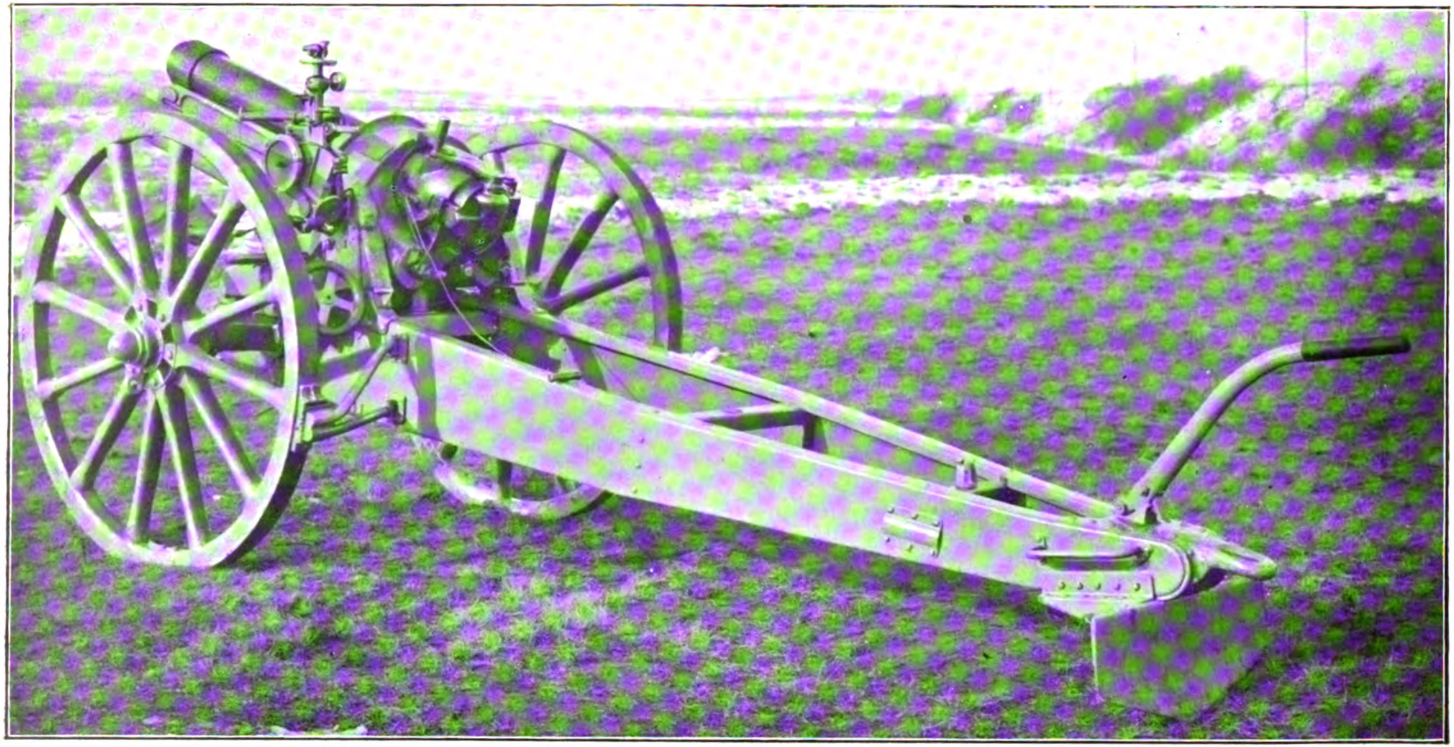
It is stated that in their later constructions Messrs. Krupp have given up the butterfly regulating valve, and now use an ordinary check-buffer.

The Vickers Maxim 4.33" Field Howitzer.

This firm have a new field howitzer, with rear trunnions. It has the single-motion interrupted screw breech action, with a retaining catch which enables the shell and cartridge to be loaded at all angles of elevation.

A balance-spring is fitted to relieve the weight on the elevating screw. The howitzer is mounted on an upper carriage, which traverses on a vertical pivot. The elevating gear gives 50° of elevation.

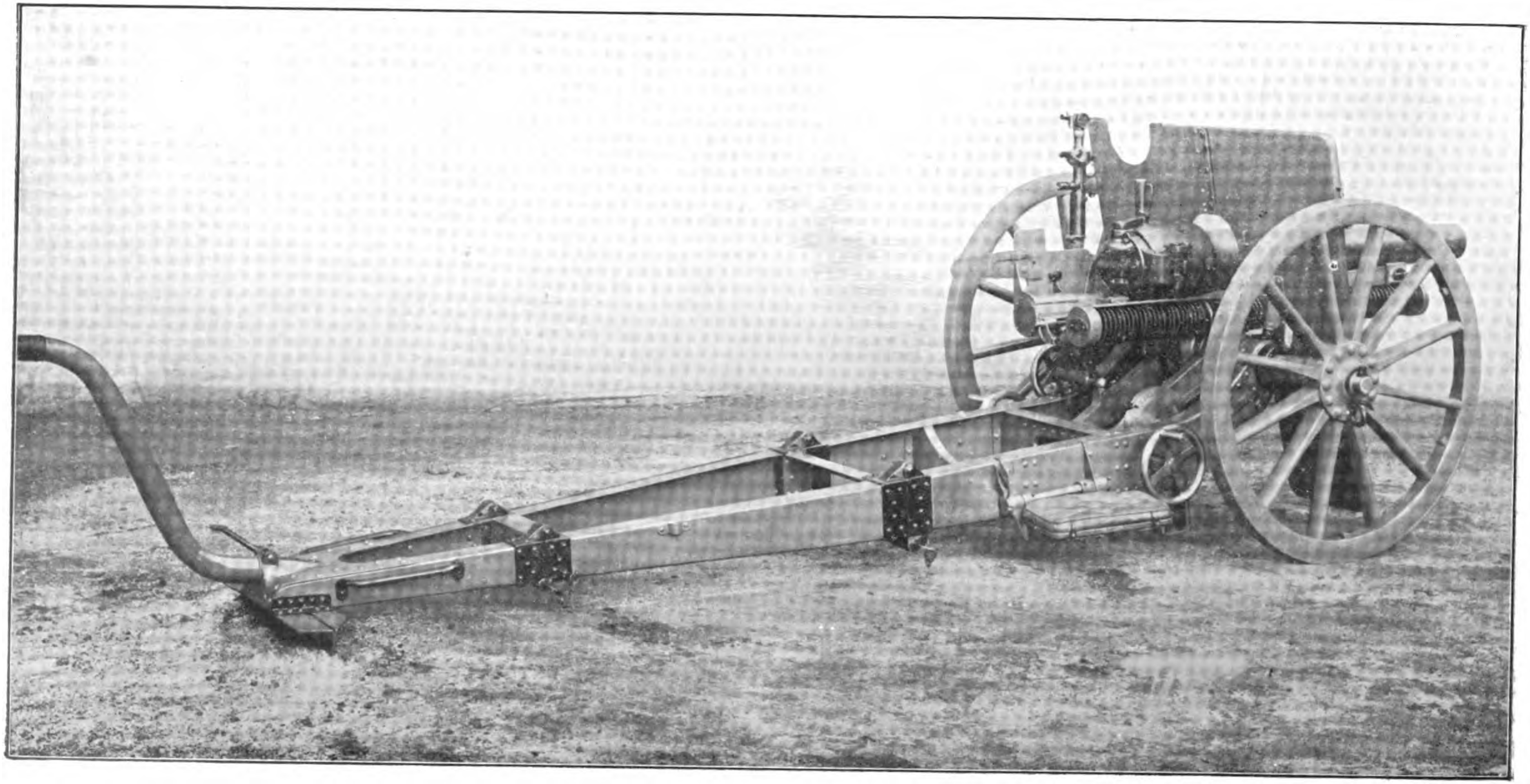
The howitzer has a constant long recoil of 37 inches; the buffer has the 3 part Vickers regulating piston already described. The howitzer is run up by twin columns of springs, of which the initial



THE VICKERS MAXIM 4.33″ FIELD HOWITZER

WITH REAR TRUNNIONS.

1909.



THE VICKERS-MAXIM 75mm. MOUNTAIN GUN.
1908.

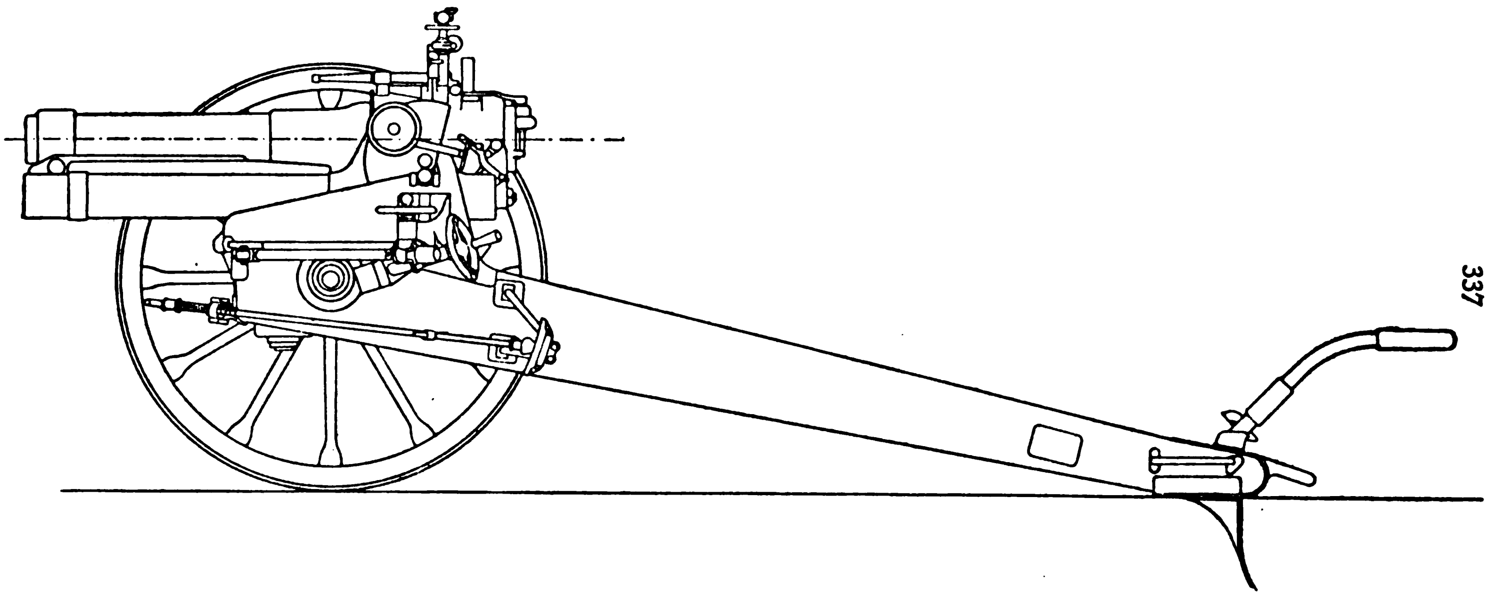


FIG. 131.
THE VICKERS MAXIM 4·33″ FIELD HOWITZER, 1909.
(Shield not shown.)

compression is maintained by rods on which they are threaded, so that a set of springs can be removed and exchanged in one minute without special tools.

The howitzer has not the independent line of sight; the rocking bar and panorama sights are compensated for drift and can be cross-levelled to eliminate difference of level of wheels.

Further details are given in the table.

The Coventry Ordnance Works 115 mm. Field Howitzer.

This firm supplied a light equipment to the British Goverment in 1908. They have now brought out a medium equipment which is somewhat heavier, but is well within Field Artillery limits of weight. The howitzer is 15.5 calibres long, which is considerably longer than the French and German howitzers. The makers claim to get remarkably accurate shooting, which may possibly be ascribed to this extra length.

The breech-action is the single-motion wedge, with repeating trip-lock; either a firing lever or a lanyard can be used. The howitzer has controlled recoil on the Ehrhardt-Vavasseur system; it traverses on a vertical pivot. The elevating gear is a toothed arc as in the Ehrhardt howitzers. The howitzer is sighted with arc and reciprocating panorama sights, with automatic correction for drift, and is fully shielded. The limbers are fitted with spring limber hooks and draught loops.

On 4′ 8″ wheels the weight is 24.25 cwt., but with the 4′ 3″ wheels used on most Continental howitzers the weight in action is under 23 cwt., which compares favourably with that of German howitzers of similar power.

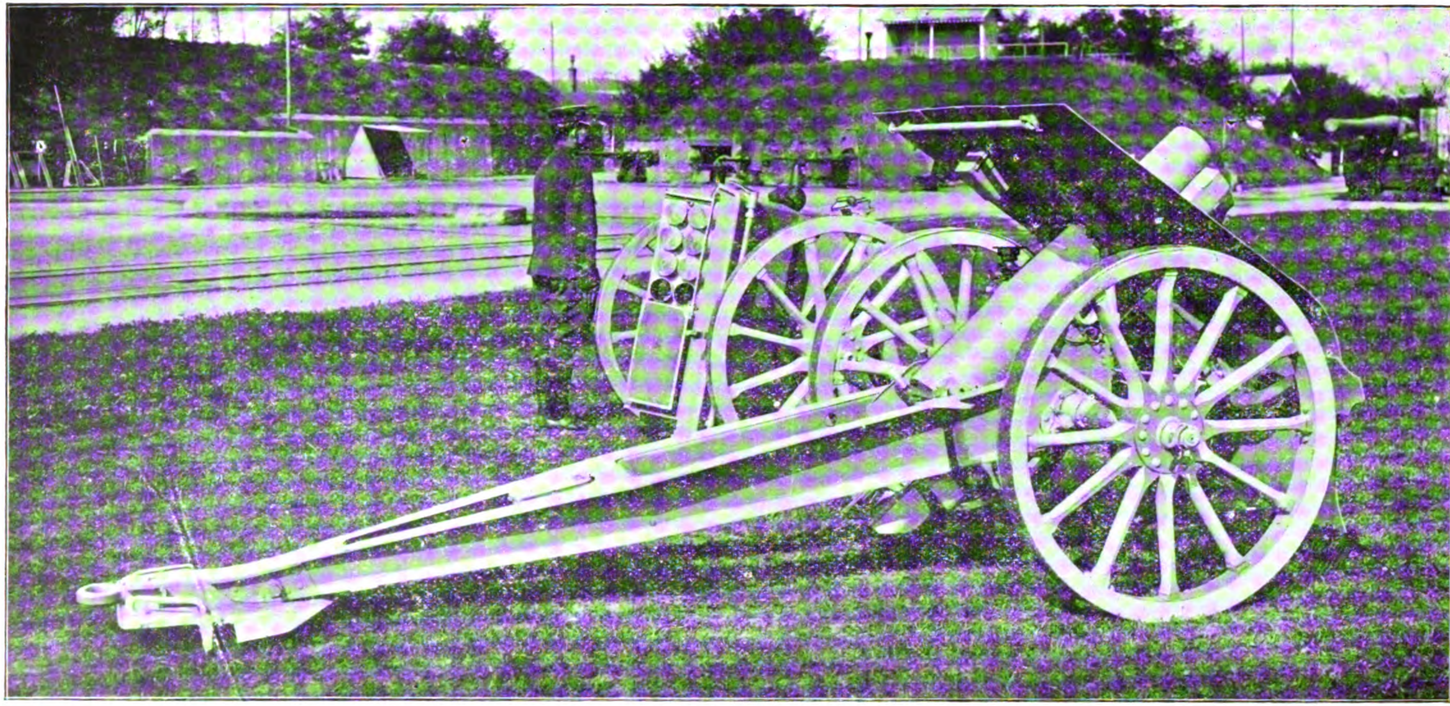
The following details are given in addition to those in the Table:

Weight of howitzer and breech action ...	8.47 cwt.
Track of wheels	62 inches
Maximum elevation...	50 degrees
Rounds in wagon body	30
Weight of wagon and limber with equipment and 46 rounds	38 cwt.

The Schneider 4.2″ Field Howitzer.

Messrs. Schneider have adopted the controlled recoil gear, which however does not come into action till the howitzer is elevated to 30 degrees; the piston is then rotated by a cam on the carriage, and the recoil shortened for all higher elevations. Thus there are only two positions of the piston valves, one for long rècoil and one for short recoil; this enables the gear to be simplified.

The hydro-pneumatic gear is illustrated on page 125 and page 334. It differs from the gear used in field guns in that the 3 cylinders are formed in the cradle, and not in a forging attached to the gun. This may be noticed in the Plates of the Schneider howitzers. The channel connecting the air-reservoir with the running-up cylinder is always below the level of the liquid with which the latter is filled, whether in the travelling position or at extreme elevation.



THE SCHNEIDER 4.2″ FIELD HOWITZER.

1909.

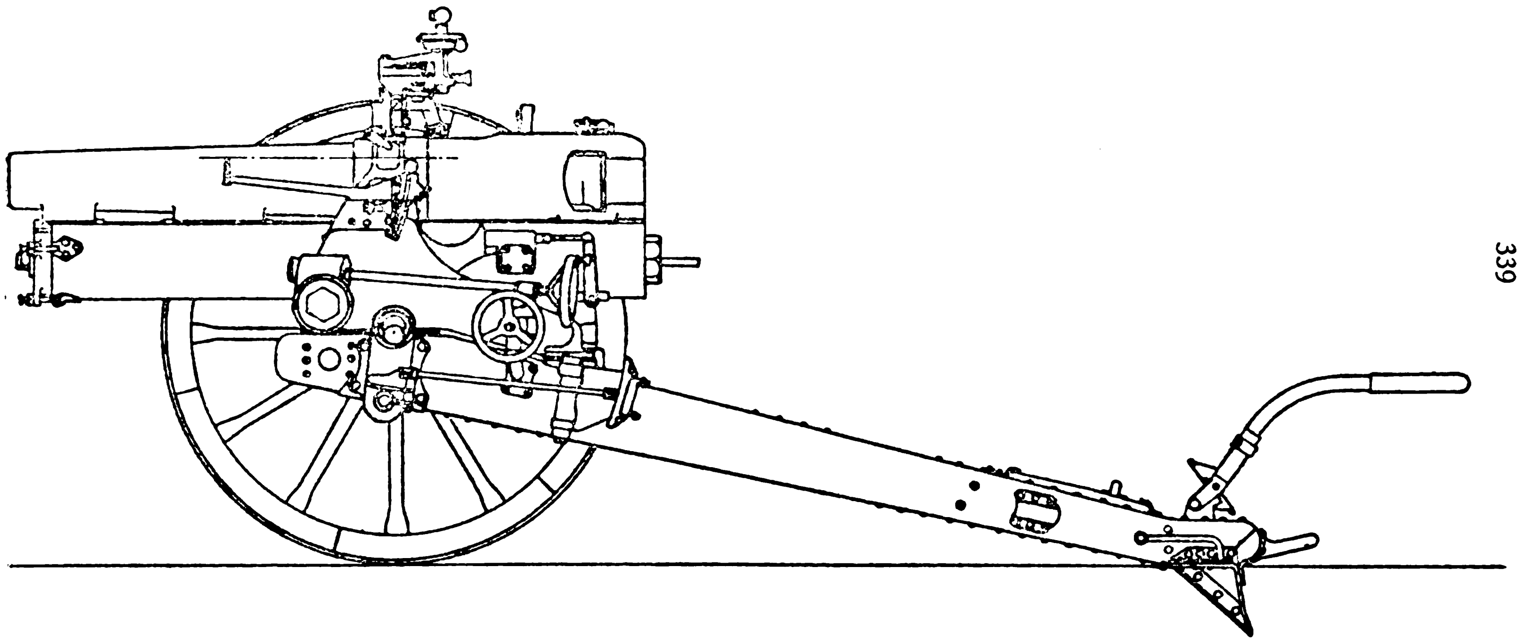


FIG. 132.
THE COVENTRY ORDNANCE WORKS 4.625″ Q.F. FIELD HOWITZER, 1910.

The figures above referred to represent the recoil gear of the Schneider 6″ howitzer, in which the recoil is not shortened at high elevations. The piston and valves of the 4.2″ howitzer, in which controlled recoil is used, are similar to the Ehrhardt-Vavasseur gear described in Chapter XV.

In other respects the howitzer is similar to the Schneider guns; it traverses on the axletree, and has the independent line of sight with panorama telescope or *collimateur*. It has very complete shield protection.

The wagon is tipped alongside the gun. The limbers are fitted with spring limber hooks and draught loops.

Further details are given in the Table.

Messrs. Schneider have also a 4.7″ howitzer firing a 45 lb. shell, weighing 23.5 cwt. in action with shield. The construction is similar to that of the 4.2″ howitzer described above.

The Schneider Automobile Howitzer Battery.

(See Plate.)

This howitzer is rather a weapon of position than a field howitzer. It possesses however many points of interest to the field gunner.

In deciding on the armament for the great entrenched camp round Lisbon it was found necessary to provide heavy howitzers capable of being quickly shifted from point to point. Owing to the nature of the ground, the expense of a tramway would have been prohibitive, and the Committee resolved to use motors. After various experiments they decided to purchase from Schneider-Canet (Creusôt) a battery of four 6″ howitzers, to be limbered up each to the breast of the carriage of the howitzer in front of it, making a train of four howitzers, the whole drawn by one motor, which also carries 64 rounds of ammunition. A second motor draws four ammunition wagons.

It has been found in practice that this motor battery can do 3¼ to 3¾ miles per hour on level roads, and half that pace up a slope of 6°. On slopes of 10° the motor goes up first and hauls the train up with a wire rope and drum. This gear is also used when necessary to haul a howitzer into position for action.

The tractor runs on petrol or oil, weighs 5 tons, and carries 7 tons of ammunition, men, and stores.

The recoil gear has already been described; the howitzer has constant long recoil, with central trunnions. Room for recoil is obtained by setting these trunnions high above the axletree, as shown in the Plate; this construction would not be admissible in a field howitzer.

The 6″ howitzer fires an 88 lb. shell and ranges 5 miles. It traverses on rollers along the axletree. The pedestal sight is identical with the French field gun sight, the elevating gear is a toothed sector on the left cradle trunnion, worked by a worm wheel. A friction clutch allows the gear to slip on firing. There is the usual rapid motion for swinging the howitzer to the horizontal position for loading. The amount of elevation given is shown on a graduated arc; the pointer is moveable as well as the arc, the former being

connected to the howitzer, the latter to the sight, so that the reading of the arc gives the true angle of elevation, independently of the angle of sight.

The breech action is the single-motion interrupted screw. There is a folding spade on the trail, and a truck or roller can be fixed under the point of the trail. This is used when hauling the howitzer into position.

The Krupp Long-Recoil Field Howitzer.

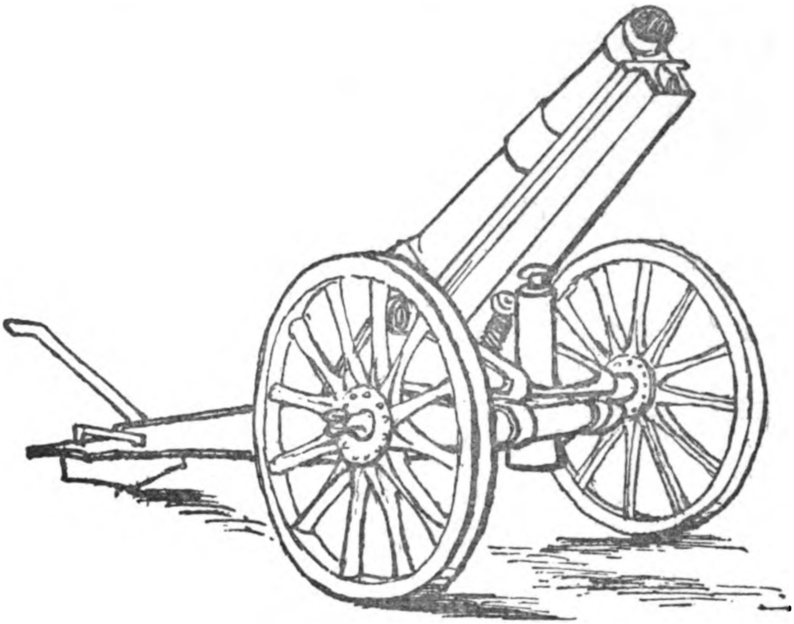


FIG. 133.
KRUPP 4.7″ Q.F. HOWITZER.
With Rear Trunnions and Constant Long Recoil.
1907.

The howitzer is on rear trunnions with constant recoil of 43 inches. It fires a 46-lb. shell with M.V. of 985 fs. The full charge is 1.05 lbs. of nitro-glycerine powder in 6 "biscuits." The recoil gear is a plain buffer with check-buffer, and a single column of springs. The elevating screw and telescopic balance spring are visible under the cradle, and the top carriage upon which the howitzer traverses is also shown in the figure.

The howitzer has the Krupp wedge breech action. It is rifled with a twist increasing from 1 in 50 to 1 in 25 calibres, and is sighted with reciprocating arc and panorama sights.

The limber has a spring limber-hook and spring draught-loops. The wagon is of the French type: 16 rounds are carried in each limber, and 30 in the wagon body.

The howitzer fires shrapnel and H.E. shell, the latter filled with lyddite or T.N.T.

The following details are given in addition to those in the Table:

Weight of howitzer and breech action	...	9.4 cwt.
Weight of shrapnel burster ...	...	7.4 oz.
Weight of H.E. burster ...	...	4.6 lbs.
Number of bullets ...	...	650
Number of bullets to the pound	...	29
Trail lift, point blank ...	...	175 lbs.
Trail lift, 43° elevation ...	...	265 lbs.
Maximum range	...	7600 yds.

This howitzer has been adopted by Switzerland and Italy, and several batteries have been supplied to Sweden.

Messrs. Krupp have also a 4.2″ howitzer firing a 31-lb. shell, which is generally similar to the 4.7″ equipment. Details are given in the Table.

Recently, Messrs. Krupp have supplied a 4.7″ howitzer equipment to Turkey. The Turks specially ordered a controlled-recoil equipment. In this howitzer the recoil is reduced to 23 inches at full elevation. It weighs 27 cwt. in action, or 1 cwt. more than the rear-trunnion howitzer; the remaining details are the same.

The Ehrhardt 4.2″ Q.F. Field Howitzer (1908.)

(See Plate.)

This is similar in general construction to the Ehrhardt Q.F. field gun. It has the device already described for reducing the gun-recoil at high angles of elevation, and a quick-motion elevating gear to bring the howitzer to the loading position. The elevating gear is a long arc fixed at both ends to the cradle. The breech action is the single-motion wedge. The howitzer is mounted on an intermediate carriage, and has the independent line of sight. The recoil is 56″ point-blank and 32″ at full elevation; this keeps the carriage steady at any elevation. Messrs. Ehrhardt fit either a 3.5 mm. shield, bullet-proof at 350 yards, or a 5 mm. shield, bullet-proof at 80 yards. Case ammunition is used.

Messrs. Ehrhardt have also a 4.7″ howitzer of similar construction. Details are given in the Table.

The Cockerill 4.7″ Q.F. Field Howitzer.

(See Plate.)

This howitzer has many points of originality.

The normal recoil of the howitzer on the carriage is 48″, but this has to be shortened to about 24″ when firing at high angles, to prevent the howitzer from striking the ground. This variable recoil is obtained by the following means.

On recoil, the liquid in the buffer is forced partly through the windage between piston and cylinder, partly through a by-pass channel under the cylinder. This channel can be wholly or partly closed by a stop-cock, which is connected to the right trunnion of the howitzer cradle so that as the howitzer is elevated it gradually closes the cock. At full elevation the cock is entirely closed, and the

only passage remaining to the liquid is through the windage. The increased resistance thus obtained shortens the recoil to the required extent.

When the howitzer runs up after recoil the liquid passes through another channel which has a cock connected to the left trunnion. When running up at full elevation this cock is automatically thrown wide open; when running up at a low angle of elevation it is only partly opened, thus ensuring smooth running up. This arrangement does away with the valves in the piston.

Another remarkable point is the shortness of the cradle guides as compared to the length of recoil. This is attained by interposing a sliding bed between howitzer and cradle, so that the howitzer slides on the bed and the bed on the cradle. The howitzer is thus well supported in the extreme position of recoil.

To increase the possible length of recoil without the howitzer striking the ground, the howitzer is made with a considerable muzzle preponderance, the trunnions of the cradle being near the breech. To lighten the labour of elevating, this preponderance is balanced by a supporting spring.

The axletree is cranked to bring the weight low.

The shield is of the folding pattern, of nickel steel, 4 mm. thick.

The howitzer has a special arrangement intended to supply the place of the independent line of sight. Two sectors are fixed in prolongation of the axis of the cradle trunnions, the outer attached to the carriage, the inner to the cradle. The sight pedestal is between them, and can be clamped to either at will. To lay the howitzer, the sight pedestal is set vertical by level, clamped to the inner sector, and the sight telescope directed at the target by working the elevating screw. The sight pedestal is then released from the inner sector and clamped to the outer, by one motion of a lever, and the elevation due to the range is given by the elevating screw; the sight pedestal is then again clamped to the inner sector, so that the sight now moves with the howitzer. This process appears complicated, but has the advantage of requiring only one elevating screw, instead of one elevating and one laying screw as used in the ordinary independent gear.

To allow for difference of level of wheels both sectors, with the sight between them, are made to pivot about an axis parallel to the axis of the howitzer, as in Scott's telescopic sight.

The graduations of elevation are read on the edge of the inner sector, the index or pointer being fixed to the sight pedestal. This answers the purpose of the range dial, since it always records the elevation of the howitzer above the line of sight.

A panorama sight is mounted on the pedestal, enabling an aiming point to the front, flank, or rear to be used. All graduations are in thousandths, and no degrees or minutes are used.

The limber is of the magazine pattern, and is mounted on india-rubber block springs.

The ammunition is fixed but separable, so as to allow the charge to be altered as required.

The following details are given in addition to those in the Table:

Total length of howitzer	56.7″
Twist of rifling, increasing from ...	4° to 12°.
Weight with breech action	8.45 cwt.
Height of axis	43″
Diameter of wheels	4 ft. 4″
Weight of wheel	150 lbs.
Weight of carriage and shield... ...	13 cwt.
Weight of limber complete without ammunition	9 cwt.
Weight of 18 rounds	8¼ cwt.

Messrs. Cockerill have also a 4.2″ howitzer of similar construction, weighing abont 21 cwt. in action and 35 cwt. limbered up.

A 4″ howitzer, of construction similar to the above, is now under trial in Belgium.

The Skoda 4.7″ Q.F. Field Howitzer.

Like the Cockerill howitzer, this has both rear trunnions and controlled recoil; the carriage is otherwise similar to that of the Skoda gun. The howitzer is unusually heavy, weighing 9.8 cwt. It has no balance spring, but an elevating arc under the muzzle end of the cradle. The weight is 24 cwt. in action without shield; the shell is said to weigh 44 lbs., M.V. 985 fs.

The St. Chamond 4.2″ Q.F. Field Howitzer.

This is similar in construction to the St. Chamond field gun already described. It is 13 calibres long and has constant medium recoil. It weighs 22.5 cwt. in action without shield, or 38 cwt. limbered up.

Q.F. Howitzer Equipments of Different Nations.

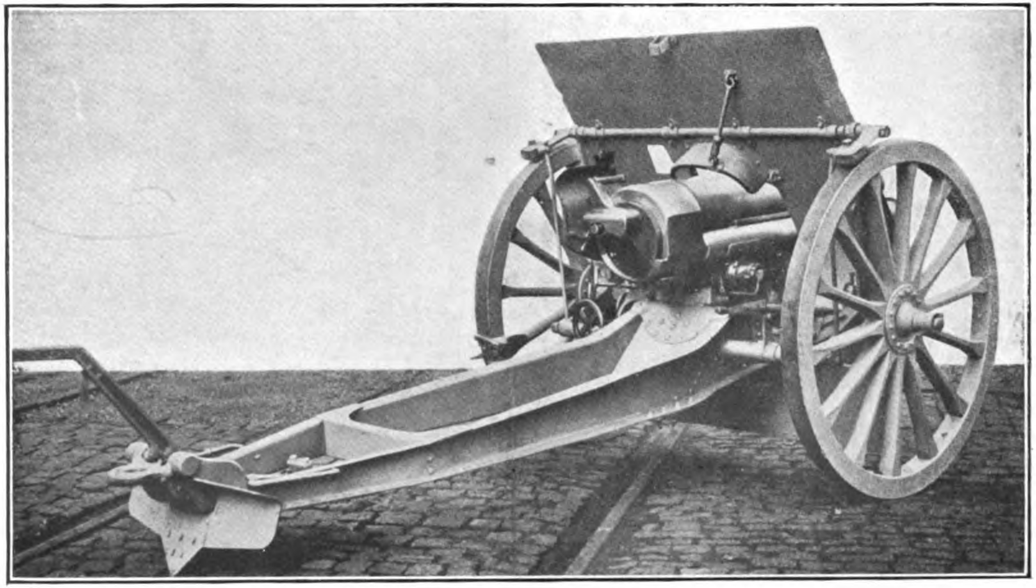
England.

It has been stated in the House of Commons that a light field howitzer designed by the Coventry Ordnance Works has been approved, and that the issue will be completed early this year. The details of the new equipment have not yet been published, but according to Press reports the howitzer has proved an exceedingly accurate weapon, while its weight in action and behind the team does not exceed that of the 18 pr. equipment.

The French Rimailho Q.F. Howitzer.

This is a heavy field howitzer of 6.1″ calibre, firing a 95 lb. shell. It is called a field howitzer because it is divided into loads not exceeding 48 cwt. The howitzer travels on a special two-wheeled cart, the howitzer carriage travels empty save for the cradle.

The howitzer has much the same compressed-air running-up gear as the Schneider-Canet howitzer already described. It has rear trunnions, allowing a recoil of 5 feet; it traverses on the axletree, and requires to be anchored with dragshoes under the wheels in the same manner as the French field gun. The elevating gear is a toothed



THE COCKERILL 4.7″ HOWITZER.

1905.

Page 345.—The issue of the 4.5″ Q.F. howitzer to the British army has been completed. The details of the weapon have not been published, but it is understood to be on the controlled-recoil system with wedge breech action. It is fully shielded, with good overhead protection, and is sighted with the panorama sight. It is a remarkably accurate weapon. The weight in action is less than that of the 18 pr.

The new German Q.F. field howitzer is of 4.2″ calibre, firing a 31 lb. "universal" shell with m.v. 985 fs. The shell has a 4-calibre head. The howitzer is 14 calibres long, and has constant long recoil with rear trunnions, and single-motion wedge breech mechanism. It is sighted with the panorama sight. The weight in action with 4 mm. shield is 22½ cwt., and the weight behind the team with 18 rounds in the limber is 37 cwt.

The new Dutch Q.F. howitzer is on similar lines to the German, but is only of 3.7″ calibre, firing a 22 lb. shell with m.v. 1080 fs. It weighs 20 cwt. in action and 36 cwt. behind the team with 24 rounds.

The new Austrian Q.F. howitzer is not yet completed. It is of 4″ calibre, firing a 32½ lb. shell with M.V. 985 fs., under 20° elevation, and 1050 fs. at higher angles. It is capable of elevation up to 70°. Both differential recoil and controlled recoil are under trial, and it is uncertain which will be adopted. It traverses on the axle, and has side shields to fill the gaps between main shield and wheels. It has the independent line of sight, and the range drum has 6 sets of graduations for the 6 charges. It is sighted with the panorama sight. The wheels are 4 ft. in diameter. It is hoped to get the weight in action down to 20 cwt.

weighs 20.5 cwt. in action and [illegible]

fs. The new howitzer will probably be of 10.5 cm. (4.13″) calibre. Both Ehrhardt controlled-recoil and Krupp constant-recoil howitzers are under trial, but no decision has yet been arrived at.

The 6″ Q.F. howitzer fires an 87 lb. shell with M.V. of 905 fs. at angles up to 65° elevation. The howitzer weighs 21 cwt., and is 11 calibres long; the breech action is similar to that of the field gun (page 276.) There is no shield; the weight in action is 43 cwt. There is no limber, but only a transporting axle with pintail. No gunners are carried; the weight behind the team is about 3 tons.

Russia.

The Russians are trying a 50-pounder field howitzer, M.V. 950 fs., weight in action with shield said to be about 24 cwt., wheels 4′ 4″ in diameter. Trials have been proceeding for 3 years and are still in progress.

Italy.

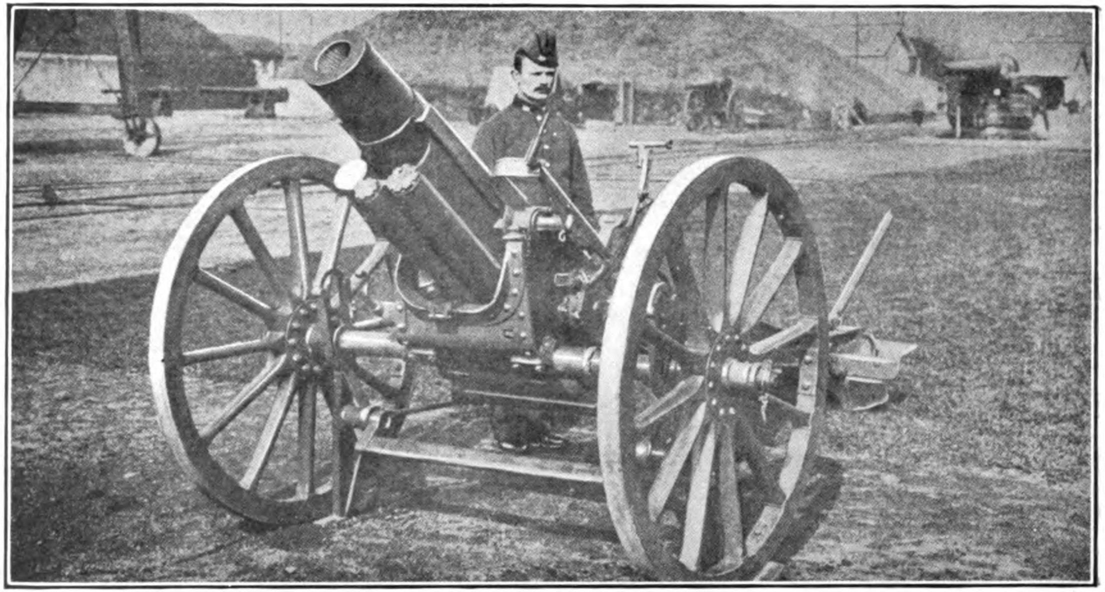
The Italians have ordered 6-inch heavy howitzers from Krupp. The question of the introduction of a light field howitzer is still undecided.

Austria.

The Austrians are converting their 4-inch spring-spade howitzer equipment to long recoil.

Switzerland has adopted the 4.7″ Krupp howitzer already described.

Spain will probably order 4.7″ howitzers from Schneider.



THE PORTUGUESE 6" Q.F. HOWITZER.

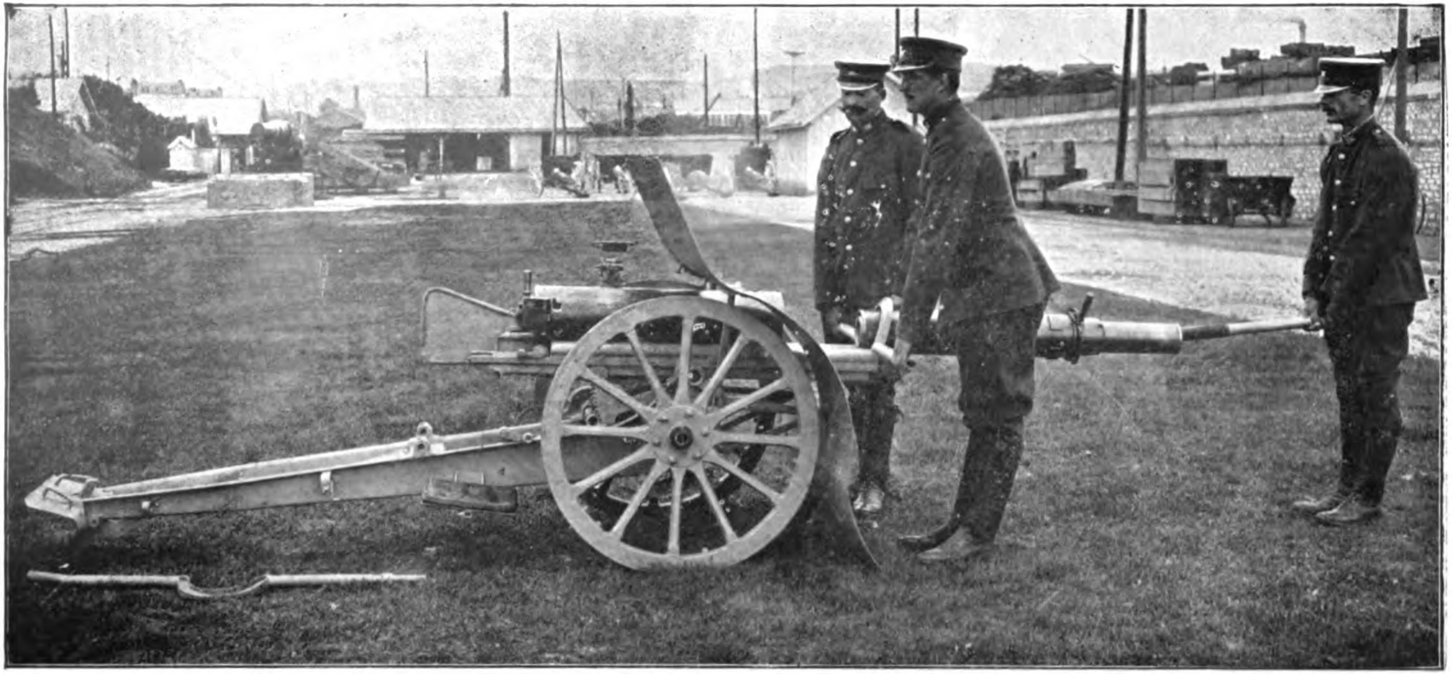
SCHNEIDER, 1903.

MOUNTAIN GUNS AND HOWITZERS, 1910.

	Vickers Maxim, 1908.	Deport, 1910.	Schneider-Danglis.	Schneider, Spain.	Schneider, Portugal.	Krupp, 1904.	Krupp, 1907.	Krupp, 1909. Diff. Recoil.	Ehrhardt.	Skoda.	Howitzers. Krupp.	Howitzers. Vickers Maxim.	Howitzers. Coventry.
Calibre, inches	2·95	2·95	2·95	2·75	2·75	2·95	2·95	2·95	2·95	2·95	4	3·3	3·3
Weight of shell, lbs.	12·5	14·3	14·3	11·65	11·2	11·65	11·65	14·3	14·3	14·3	24·5	20	20
Muzzle velocity, f.s.	1150	950	1115	985	1075	920	1320	1015	900	900	740	910	860
Breech action	S.B.	E.S.	S.B.	S.B.	S.B.	W.	W.	W.	W.	S.B.	W.	W.	W.
Whether semi-automatic	No	Yes	No	No	No	No	Yes	Yes	No	No	No	No	No
Gun in one piece or two	Two	One	Two	One	One	One	Two	One	One	One	Two	Two	One
Line of sight, whether independent... ...	Yes	No	Yes	Yes	Yes	No	No	No	No	No	No	No	No
Traverse on pivot or axletree	P.	A.	A.	A.	A.	P.	P.	P.	P.	P.	P.	A.	P.
Greatest elevation, degrees	15	45	30	20	20	20	18	28	30	32	45	45	42
Diameter of wheels, inches	36	28·5	35·5	35·5	35·5	32	41·6	32	35·5	32·5	35·5	36	36
Weight in action with shield, cwt.	10	6·45†	10·4	9·9	8·55	7·2†	11·2	9·9	8·45	11·1	21	9·9	10·1
Heaviest load, with saddle, lbs.	296	305	300	315	280	345	310	315	310	328	325	270	320
Number of loads, without shield	4	3	5	4	5*	4	6*	5*	5*	5	12	6	5

NOTE.—The V.M. gun can fire up to 20° elevation with shortened trail. The Krupp gun can fire up to 28° elevation with super-elevating block.

* Including 3 mm. shield. † Without shield.



THE SCHNEIDER-DANGLIS MOUNTAIN GUN.

1907.

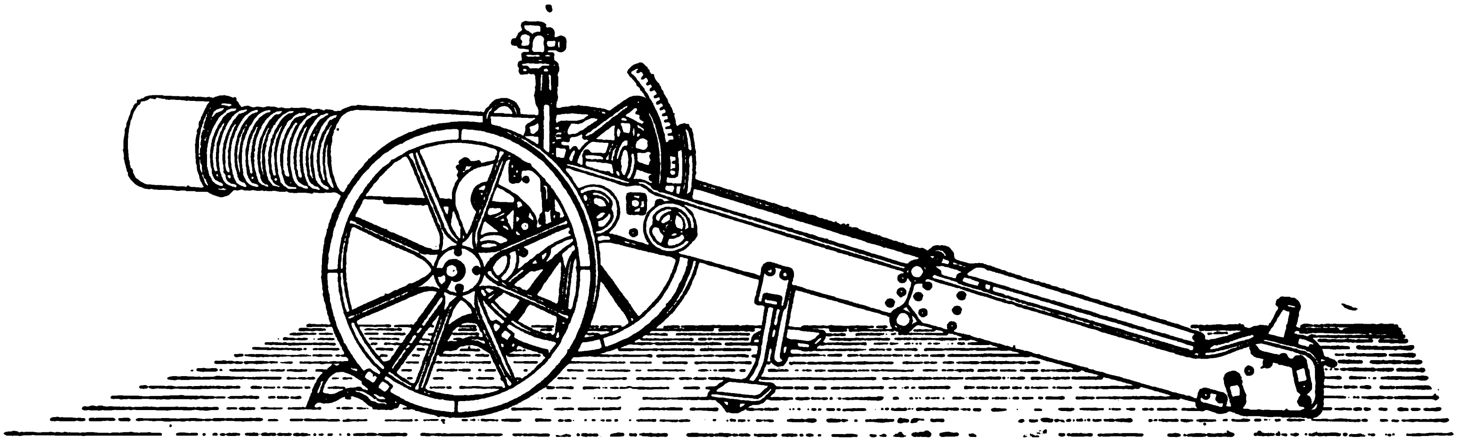


FIG. 135.
THE DEPORT 14.3-pr. MOUNTAIN GUN. FORWARD POSITION. 1910.

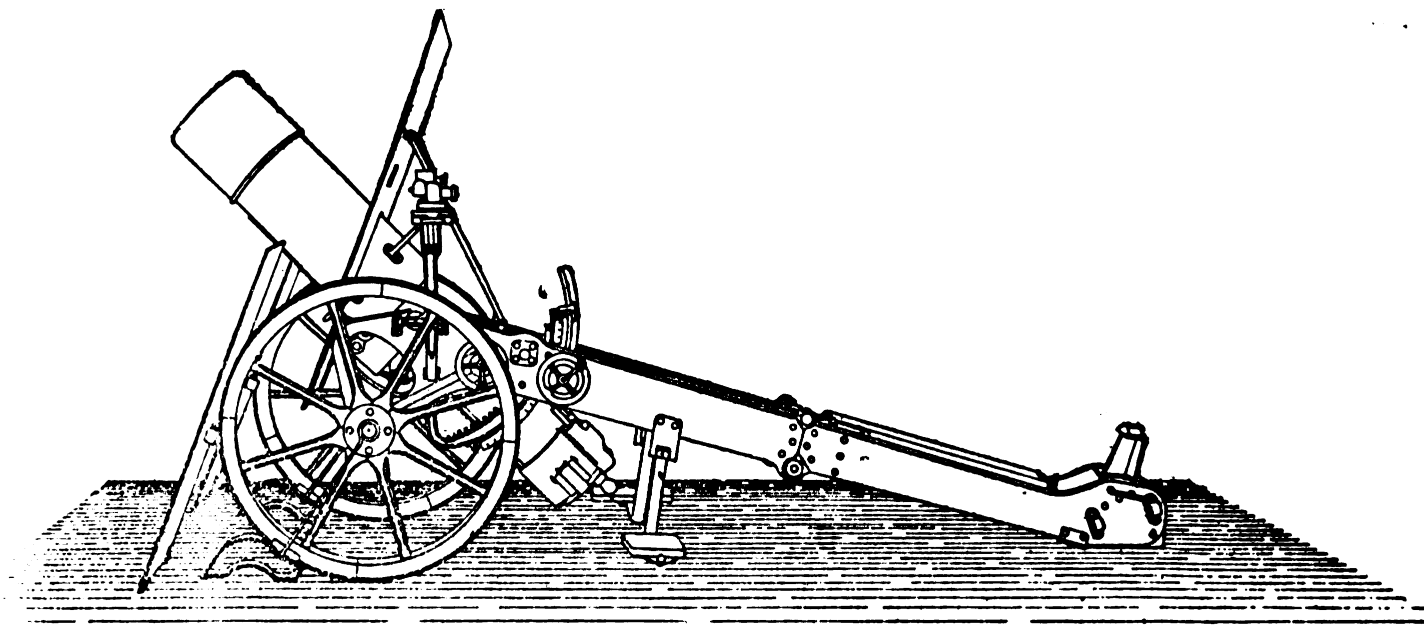


FIG. 136.

THE DEPORT 14.3-pr. MOUNTAIN GUN WITH DIFFERENTIAL RECOIL. 1910.

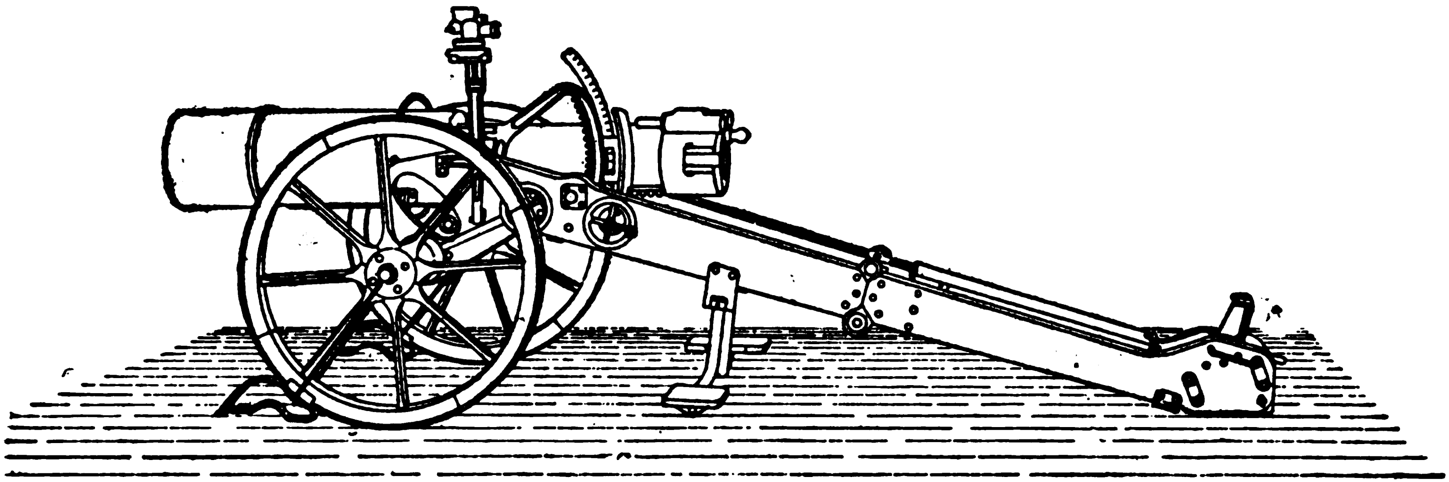


FIG. 137.

THE DEPORT 14.3-PK. MOUNTAIN GUN. LOADING POSITION. 1910.

The carriage is held from recoiling by the Deport "spike," which is a stout steel bar of T section, driven in with a hammer, so as to nail the point of the trail to the ground. The spike is held by a ratchet at any desired depth. The inventor claims that it is specially suitable for mountain work, since it gives a good hold on rocky ground if only driven down a few inches. The spike has two other functions; it prevents the trail from lifting if the gun misses fire, and it prevents any forward movement of the carriage during the run-up, which might throw the gun off the target. This is an important point with a differential recoil gun. In this action the spike is assisted by a spring scotch suspended in front of each wheel, as seen in the figures. It is claimed that the spike and hammer weigh much less than the ordinary spade, and are more efficient.

The breech mechanism is the eccentric screw, as in the French service gun. It has a semi-automatic attachment which throws open the breech and ejects the cartridge during the recoil. This enables a rate of fire of 25 rounds per minute to be easily attained.

In most semi-automatic equipments the cartridge case is ejected during the run-up, but with a differential recoil gun, the gun is already re-loaded and ready to fire before the run-up, commences. The gun shown in the figures has the "concentric screw" breech mechanism, in which a vertical wedge is actuated by a screw concentric with the bore. This is in effect the old Armstrong R.B.L. action made up as a single-motion action. It has been discarded as too complicated, and the ordinary eccentric screw is now fitted. The gun is sighted with ordinary and panorama sights, which reciprocate to eliminate difference of level of wheels. It traverses on the axletree. A pair of small check-buffers are fitted to ease any forward jerk on the carriage in case of a misfire.

The following additional details are given:

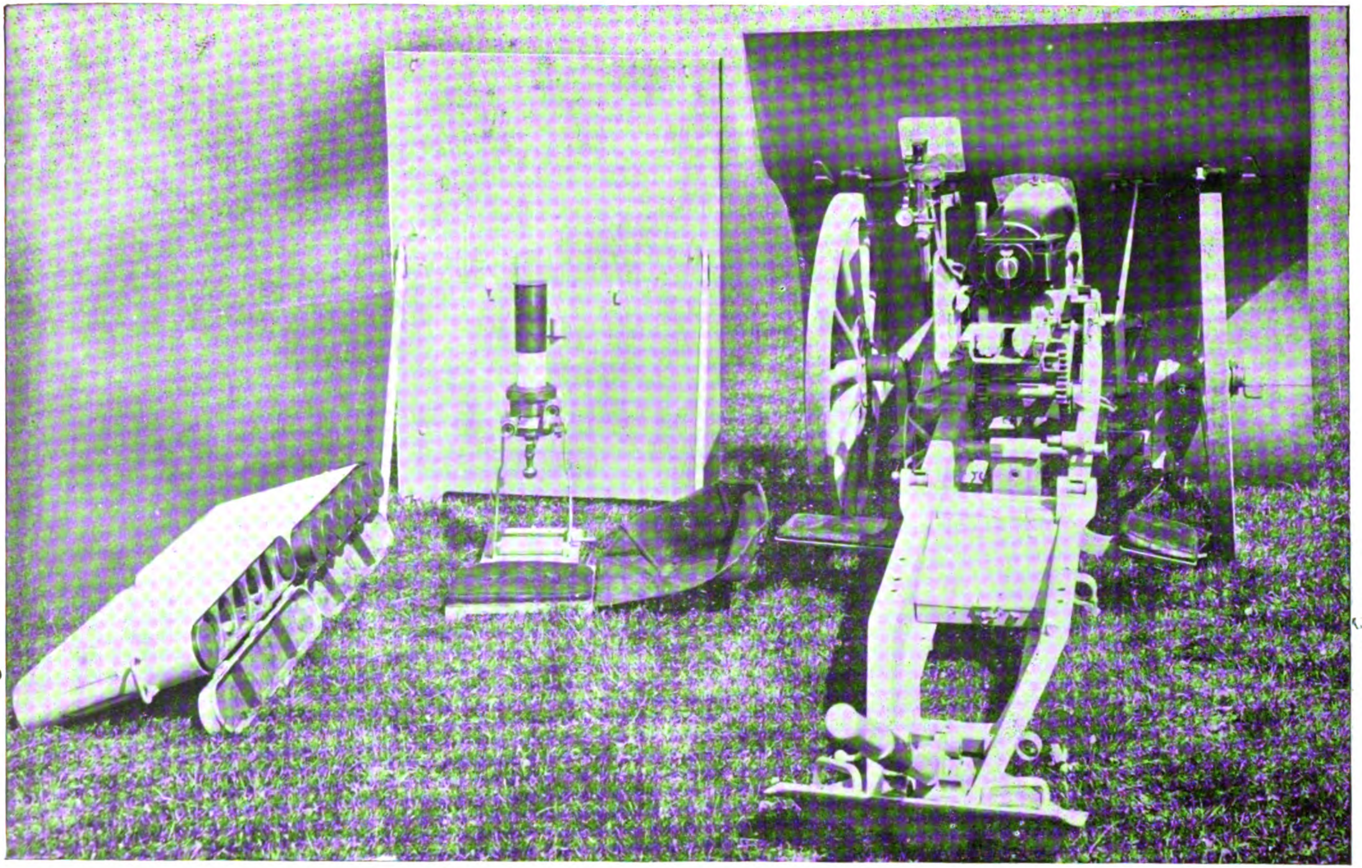
Calibre	2.95 inches
Length, calibres	17
Length of trail	6.25 feet
Height of axis	23 inches
Elevation	45 degrees
Traverse each way...	3 "
Diameter of wheel...	28.5 inches
Track	34.5 inches
Weight of gun and breech mechanism ...	235 lbs.
Weight of cradle and springs	250 lbs.
Weight of trail and wheels	235 lbs.
Weight of 4 mm. shield	120 lbs.

The equipment is carried on 3 mules; the shield, with 4 rounds of ammunition, forms a fourth load.

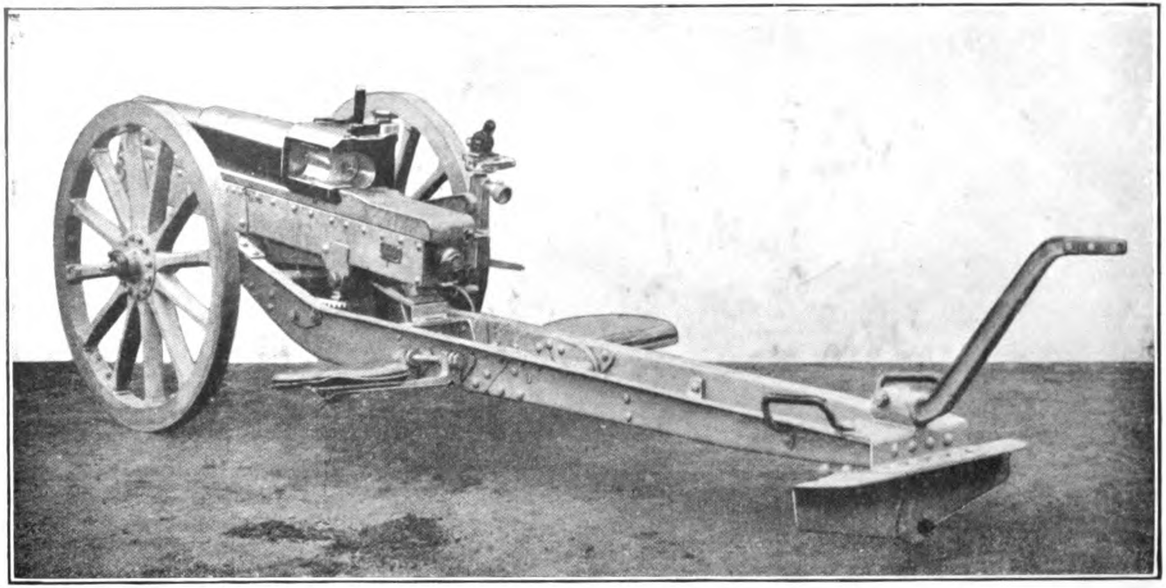
Schneider.

(See Plates.)

The guns made by this firm for Spain and Portugal are reduced copies of their field equipment. They are light and handy little guns (see Table), but they have been somewhat eclipsed by the far more powerful Schneider-Danglis gun made for Greece. This is a 5-mule equipment, with a gun in two pieces, as illustrated on page 349.) The



SCHNEIDER MOUNTAIN GUN.
1909.



THE KRUPP SEMI-AUTOMATIC MOUNTAIN GUN.
1905.

gun is dropped into a sleigh on the cradle, which contains the buffer and compressed-air running-up gear. The axletree is normally cranked downwards, but can be cranked upwards for firing, enabling 30 degrees of elevation to be obtained. The gun traverses on the axletree, and, like all the Schneider equipments, has the independent line of sight, with non-reciprocating pedestal sight. Either the panorama telescope or the *collimateur* is fitted. The gun fires shrapnel and H.E. shell, the latter filled with ammonal or T.N.T.

The gun is efficiently shielded, as shown in the Plates: the gun shield and ammunition shield form a separate mule-load.

The following details are given in addition to those in the Table:

Length of bore	16.6 calibres
Weight of chase	235 lbs.
„ jacket and breech action ...	226 „
„ cradle and recoil gear ...	264 „
„ front half of trail and axle ...	249 „
„ rear half of trail and wheels ..	264 „
„ two shields	229 „
Rate of fire per minute	25 rounds.

Thirty of these guns have been supplied to Greece, and it is stated that a number have been ordered by Russia.

The Krupp Q.F. Mountain Gun (1904).

(See Plate.)

This gun is distinguished by the Krupp *sleigh*, already referred to, which is interposed between the gun and the cradle, and which facilitates the assembling of the gun for action. Except for this and for the divided trail, the equipment is similar to the Krupp Q.F. field gun.

The following details have been published in addition to those given in the Table:—

Length of bore	34.75″.
Weight of wedge	42.8 lbs.
Number of grooves	28
Depth „	0.019″
Width „	0.232″
Twist „	1/45 to 1/25
Length of rifling	30″
Number of bullets in shrapnel	225
Number of bullets to the pound	41
Diameter of chamber at rear	3.14″
„ „ front	3.015″
Sighting radius	28.3″
Max. elevation	20°
Max. range	4600 yards

No shield is included in the equipment, but a shield 0.14 thick weighing 80 to 100 lbs. is supplied if desired.

The net loads are as follows, not including saddle and equipment:—

Gun mule	264 lbs.
Cradle mule	220 lbs.
First trail mule, with axle...	185 lbs.
Second trail mule, with wheels and shafts ...	209 lbs.

The cradle forms an awkward load, being 4′ 6″ long. With 60 lbs. of saddle and equipment it weighs 350 lbs., which is beyond the limit considered advisable in our service.

The Krupp Semi-Automatic Mountain Gun (1905).

(See Plate.)

This is a small-bore gun throwing a shell of only 6 lbs. with a high velocity. The semi-automatic action is as follows: A rod connected to the breech action leads forward on the right-hand side of the gun, and has a projection on its fore-end. There is a tripper on the cradle which allows this projection to pass during recoil. On running-up the tripper catches the rod, which throws open the breech and ejects the cartridge-case. The breech then remains open, and is held open by the extractor. When the fresh cartridge is inserted, as soon as it pushes home the extractor the wedge breech-block is released and closes by a spring.

This action enables one of the gunners serving the gun to be dispensed with. This is important in view of the small amount of cover afforded by the shield of a mountain gun.

This gun travels either on mule-back or in shaft-draught. It is intended either as a mountain gun or as a "battalion gun" to advance with the infantry firing line.

The Krupp Mountain Sight.

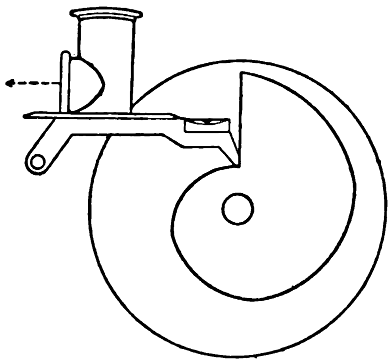


FIG. 138.
DIAGRAM OF KRUPP MOUNTAIN SIGHT.
(View from left side.)

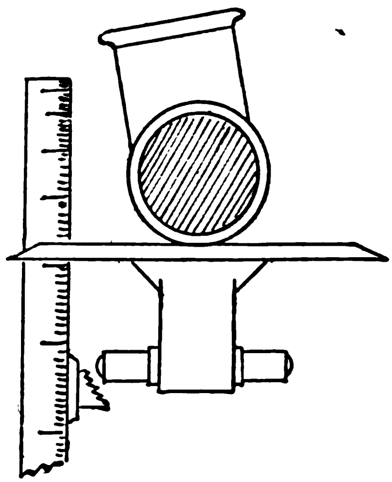


FIG. 139.
DIAGRAM OF KRUPP MOUNTAIN SIGHT.
(Front view.)

This consists of a short telescope bent at right angles, mounted on a rocking bar. One end of the bar is supported on a spiral cam; on the same axis as the cam is a drum about 24″ in circumference, graduated in metres of range. The bar also carries a clinometer level adjustable for angle of sight. The whole sight can be mounted on a pivot parallel to the axis of the gun, so that it can be cross-levelled to correct for difference of level of wheels. The telescope is mounted on a graduated circular plate, so that it can be directed on an aiming point at any angle.

The telescope has a field of about ten degrees, and is of low magnifying power. On looking down into it from a distance of a few inches the layer sees a brightly illuminated picture of the foreground, with a pointer in the middle of the field.

The gun is sighted on the right-hand side at the extreme rear end of the cradle, well clear of the wheels. The telescope is inclined to the right, so that the layer has not to put his head behind the recoiling gun.

The whole sight is remarkably simple and compact; it has no verniers or other complications, and there is nothing about it likely to go wrong. It would be an easy matter to put a fuze scale and corrector scale on the face of the drum.

The Krupp Differential Recoil Mountain Gun.

(See Plate.)

In this gun the differential recoil gear is assisted by a buffer, so that only part of the recoil is taken on the springs. This enables the gun to be fired from the forward position at the first round. The buffer is under the gun, and the twin spring columns are on either side. The cradle is on rear trunnions, which enables the carriage to be balanced so that the trail lift in the loading position is only 150 lbs. The buffer is prolonged to the front so as to bring the gun smoothly to rest in case of a misfire.

This gun has the semi-automatic breech action already described.

It is a very powerful mountain gun, firing a 14.3 lb. shell with M.V. of 1015 fs.

The perforated casing seen in the Plate serves to protect the layer from being struck by the gun in its backward or forward movement.

The Ehrhardt Mountain Gun (1904).

(See Plate.)

This is a 2.95″ gun firing a shell of 11 lbs. 10 oz. with M.V. 900 fs. It is a reduced copy of the Ehrhardt field gun, having a cradle pivoted in a socket in the axletree. The trail is of Y shape and folds for travelling. The gun has the Ehrhardt wedge breech and is sighted on the cradle with arc and panorama sights. The elevating gear gives no less than 25° of elevation. The shield is unusually large and is recessed to fit over the wheels and to project beyond them. It weighs 99 lbs. It may be noted that a shield so small as to fit between the wheels of a mountain gun affords little real protection. If a mountain gun is to have a shield at all it is as well that it should be a serviceable one. A pair of shafts is carried for travelling on roads.

The equipment is divided into four equal loads of 242 lbs. net, namely, gun, cradle and shield, trail and wheels, axle and shafts. The cradle is unusually light, weighing only 143 lbs.

The Ehrhardt Controlled Recoil Mountain Guu (1906).

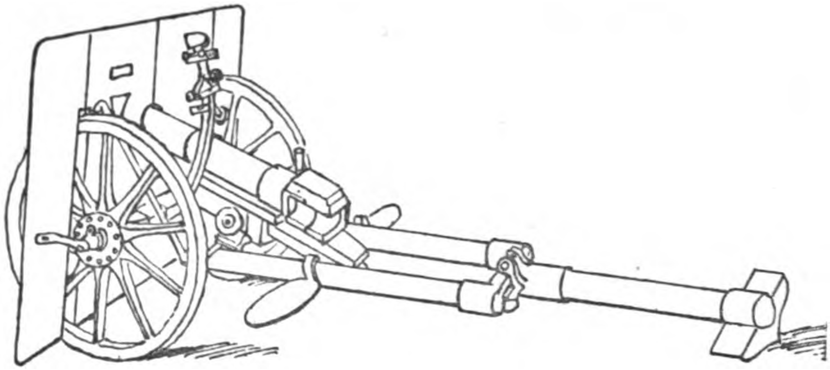


FIG. 140.
EHRHARDT 75 mm. CONTROLLED RECOIL MOUNTAIN GUN.
In Recoil Position.

This is a powerful gun, throwing a shell of 14.3 lbs. weight, M.V. 900 fs.

It is but little heavier than the Ehrhardt 12 pr. mountain gun; the extra power, combined with steadiness, is obtained by the controlled recoil gear already described, which enables the gun to be kept low on the carriage without any risk of the breech striking the ground when firing at elevations up to 30 degrees. The equipment is otherwise similar to the 12 pr., but the shield is only 3 mm. thick instead of 3½ mm., and weighs 77 lbs. Another point of difference is that in the 14.3 pr. the guide-blocks are not permanently fixed to the gun, but remain on the cradle when the gun is lifted out of them, on the same principle as that of the Krupp sleigh.

The gun is carried in four equal loads of 210 lbs. net; a fifth mule carries the shields for two guns. The four loads are: gun, cradle with guide-blocks, trails and wheels, axle and shafts.

Two batteries of Ehrhardt mountain guns were supplied to Portugal for the Angola expedition which was to have started in 1906; and two batteries have been supplied to Holland for use in Further India.

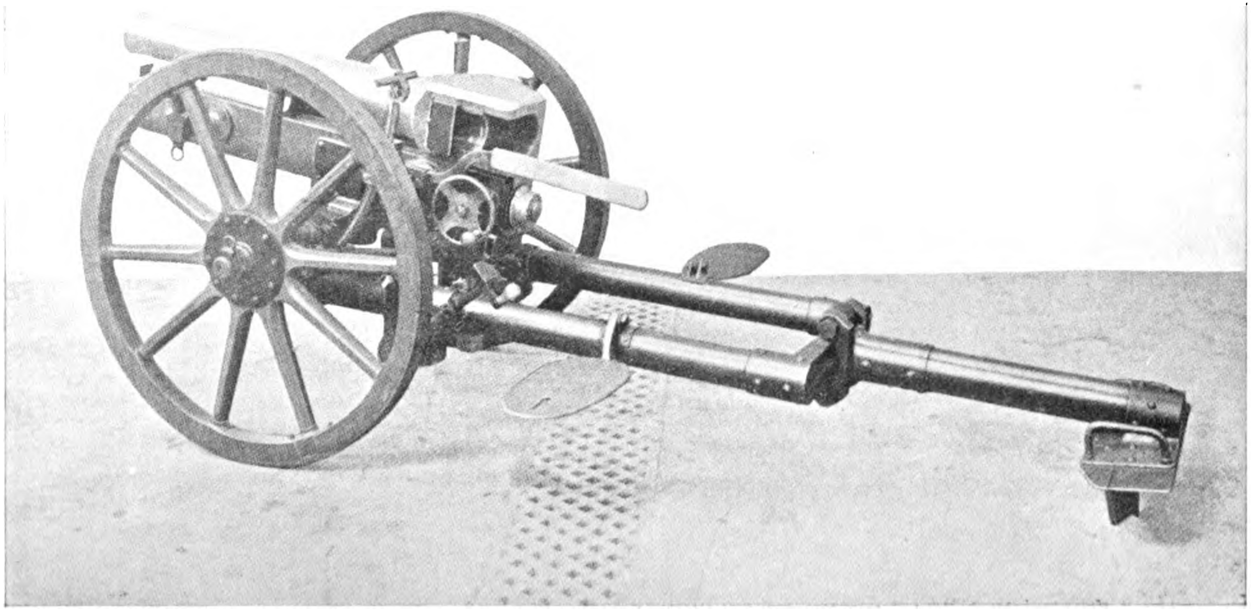
Skoda.

(See Plate,)

This is a 14.3 pr. 5-mule equipment. The gun is in one piece, and has the single-motion interrupted screw breech mechanism. It lies in a sleigh, and is sighted on the cradle with arc and panorama sights. The buffer is of the ordinary type, with check-buffer; telescopic springs are used. The guides on which the sleigh slides are *inside* the cradle. The axletree can be cranked upwards or downwards as in the Schneider equipment.

Details are given in the Table.

Page 358.—The Skoda differential recoil mountain gun fires a 14.3 lb. shell with M.V. 1120 f.s. It is capable of elevation up to 40°, and forms 4 loads of 230 lbs. net without shield.



EHRHARDT MOUNTAIN GUN.

1904.

The Skoda 1910 mountain equipment is now under trial by the Austrian Government.

Bethlehem, U.S.A.

This equipment is of novel construction. The gun, when brought into action, is dropped into a sleigh on the same principle as in the Krupp mountain equipment. But the Bethlehem sleigh contains, or rather consists of, the twin buffers and the springs, which are inside them. The whole of these parts recoil with the gun except the piston rods.

There is no cradle, but a guide bar upon which the gun and the sleigh recoil; the front of this is forked and turned up to receive the end of the piston rods.

This construction is ingenious, and well suited for a mounted gun. The weight of the gun is kept at a minimum, and all working parts are well protected. The gun is a powerful one; it is of 3 inches calibre, throwing a 12 lb. shell with M.V. of 1,100 fs. and M.E. of 100 foot-tons. The gun, carriage, and 8 rounds make 4 loads of 206 lbs. net, without saddle.

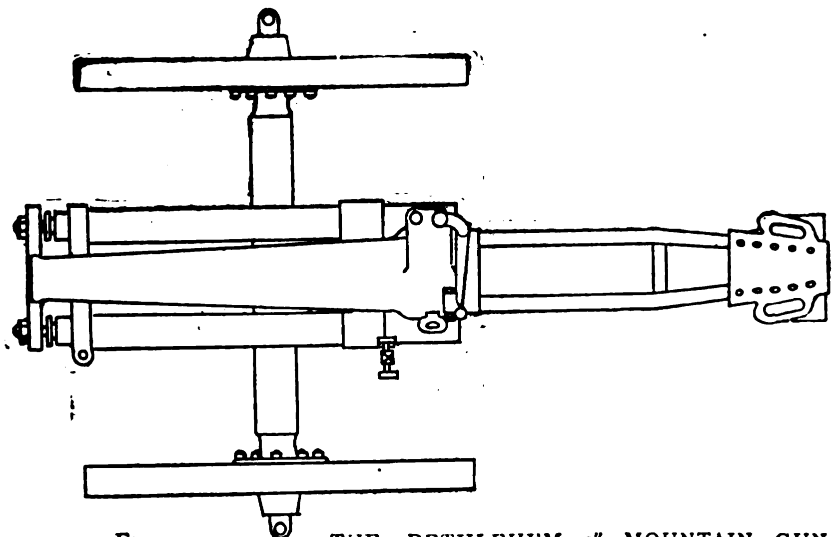


FIG. 141. THE BETHLEHEM 3" MOUNTAIN GUN.

THE Q.F. MOUNTAIN HOWITZER.

A mountain howitzer is a gun throwing a heavy shell at high elevation, and capable of being transported on pack animals.

The difficulty in the way of its construction lies in the small space available between the howitzer and the ground, which renders it difficult to allow of long recoil without the breech striking the ground on discharge. On the other hand, the mountain howitzer is not expected to travel across country on its wheels, so that it can be set proportionately higher than a field gun.

Attempts have been made to overcome the above difficulty by a combination of rear trunnions and controlled recoil, but with no great success. More recently, the Schneider revolving cranked axle-

tree has been applied to the mountain howitzer. But now that it is possible to produce a 14.3 pr. mountain gun, which can be fired at angles of elevation up to 30 degrees, or 45 degrees with differential recoil, the necessity for the provision of a mountain howitzer has become less urgent.

Several of the mountain guns might be converted into howitzers merely by using a gun of the same weight but larger bore; thus the Schneider-Danglis gun could fire a 25 lb. shell with M.V. of 870 fs. from the existing carriage, without increasing the weight of the equipment. The same applies to the Deport gun, now a 3-mule equipment, if the gun were made in two parts, so as to form a fourth mule-load. Our own 7 pr. screw-guns used to fire a double shell when explosive effect was required, but these extra long projectiles shoot so badly that they are not likely to be used in a modern equipment.

Generally speaking, it may be said that only the nations armed with 12 pr. mountain guns are interested in the Q.F. mountain howitzer. For the nations which have still to re-arm, it is an open question whether a 14.3 pr. mountain gun, capable of being used as a howitzer, would not be more useful than a 12 pr. gun equipment and a 25 pr. howitzer equipment.

un fine *The Krupp Mountain Howitzer.*

26.5 This is a good specimen of existing equipments. It is of 4-inch calibre, firing a ~~25~~ lb. shell with M.V. of 740 fs. The gun is in two
ul. mth pieces, weighing 265 lbs. each, much as in the Schneider-Danglis gun. It has an ordinary non-automatic wedge breech action, and is 12
V 820 calibres long; the recoil gear is the same as in the Krupp field gun, but with rear trunnions, giving a constant long recoil of 27 inches.

The following details are given in addition to those in the Table:

Rifling	1/25 to 1/50 calibres
Height of axis	37 inches
Track	36 inches
Thickness of shield ...	3.5 millimetres
Traverse each way ...	4 degrees
Number of shrapnel bullets...	350
Number to the pound ...	28
Weight of H.E. shell burster (T.N.T.)	15.9 oz.
Greatest Range	4400 yards

The latest (1910) Krupp mountain howitzer is more powerful than the above; it is of 4.2″ calibre, firing a 26.4 lb. shell with M.V. of 933 fs. The weight in action is 19.5 cwt.

Vickers Sons and Maxim have a mountain howitzer of which some details are given in the Table. The howitzer is not jointed, but the breech ring and mechanism are carried separately, thus reducing the weight on the gun mule. The equipment is divided into six loads. Including saddle and equipment the total loads are as follows:—

1.	Howitzer	270 lbs.
2.	Buffer and springs, etc.	269 „
3.	Cradle, breech-ring, and breech action	269 „
4.	Front end of trail and shafts ...	259 „
5.	Rear end of trail, tools, etc. ...	267 „
6.	Wheels, axle, and stores	258 „

These loads are well within the limits laid down in Chapter XX.

Addenda to April, 1910.

Page 360.—The Krupp mountain howitzer now fires a 26.5 lb. shell with M.V. of 820 fs.

Page 361.—The new Austrian 4" Q.F. mountain howitzer is not a pack equipment. The carriage travels empty, attached to a small limber drawn by 2 horses; this is followed by the cradle and the howitzer, each on a 2-wheeled cart. The track of the wheels is 36 inches. For rough ground the wheels can be removed, and the trail and the cart bodies then form sleighs. The H.E. shell weighs 31.5 lbs., M.V. 950 fs. For each howitzer, 60 H.E. shell and 60 shrapnel are carried on pack animals, each of which carries 6 rounds. A further 480 rounds per howitzer are carried with the ammunition column.

Page 361.—Russia has now ordered 400 Schneider-Danglis mountain guns, to be made at Putiloff. The gun differs from the Greek gun in that it has not the independent line of sight and the swinging block is not set eccentrically. The M.V. has been increased to 1235 fs. The heaviest load is 245 lbs. net.

Page 361.—A H.E. shell with burster of 12 oz. T.N.T. has been introduced for the Spanish mountain gun.

Page 361.—Turkey is holding competitive trials in which Krupp, Ehrhardt, Schneider, Skoda and the Deport gun were represented. It is stated that in the preliminary trials all but the Ehrhardt and the Schneider-Danglis gun were eliminated.

The Coventry Ordnance Works.

This firm has a mountain howitzer equipment of which the details are given in the Table. It differs from the V.M. equipment in that the M.V. is 50 fs. less; this enables the weight of the howitzer and breech action to be kept down to the 265 lbs. limit. The howitzer is 14.7 calibres long as against 13 for the V.M.; this enables the required muzzle energy to be obtained with less metal in the howitzer. The total weight of gun and carriage is about the same in the two equipments.

Q.F. MOUNTAIN EQUIPMENTS OF DIFFERENT NATIONS.

France.

The differential recoil mountain gun has been adopted *en principe*, but it is not proposed to re-arm until the re-organization of the field artillery is completed.

Germany.

Trials with 75 mm. mountain equipments were commenced in 1909 and are still proceeding. Krupp, Ehrhardt and the Government factory, Spandau, are competing.

Austria.

The Austrians have made some of their field howitzers available for mountain work by putting them on narrow-gauge carriages of 1 metre track. This system is of great value in Central Europe, where most mountains, up to the snow line, are traversed by fairly easy tracks. But it does not constitute a true mountain equipment.

Trials of mountain guns are announced to take place early this year.

Russia.

The Russian 1904 Q.F. mountain gun was a 14.3 pr., M.V. 920 fs., forming 5 mule-loads. It was not very steady in action, and the gun load (221 lbs. net) was considered too heavy for Russian ponies. The Schneider-Danglis mountain gun already described has been successfully tried in Russia, and the Artillery Committee have recommended its adoption. As however the loads with this equipment vary from 226 to 264 lbs. net, it is to be presumed that the pattern adopted by Russia will be lighter than that made for Greece.

Italy.

The Italians are trying a 65 mm. (2.56") mountain gun of their own design. The trials are still incomplete. Thirty batteries are to be formed.

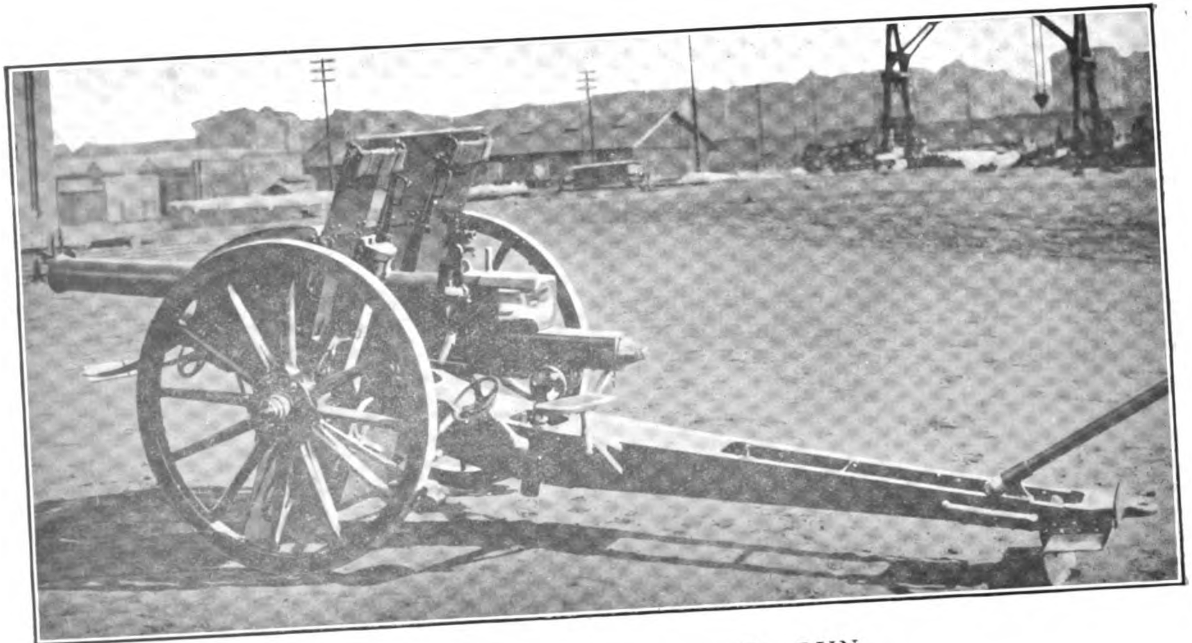
Spain and Portugal.

These countries have Schneider mountain equipments, of which the details are given in the Table.

Japan.

The present Japanese gun is a smaller edition of their 1901 field gun described in the last chapter. It is not a true quick-firer. It fires shrapnel and H.E. shell of 13.2 lbs., M.V. 900 fs. Fixed ammunition is used. The gun is of 2.95″ calibre, 40″ long, rifled with uniform twist of 1 in 25 calibres, swinging block breech action, weight 220 lbs. The trail is in two parts. The carriage gives 30° elevation and 10° depression. The height of the wheels is 40″, track 23″. The equipment forms four mule loads.

The new Japanese mountain gun has not yet been issued. It is stated that it has compressed air running-up gear, and that the maximum load has been fixed at 275 lbs. including saddle. As however the Japanese have now reduced their mountain artillery to 10 batteries (including one depôt battery) they will presumably not be inclined to spend money on them at present.



THE SKODA 75mm. Q.F. GUN.

1905.

CHAPTER XXXVI.

BALLISTICS OF MODERN GUNS.

In this chapter it is proposed to give a number of data which have been collected as to the performance of different guns. These data are not all equally reliable; some, which are marked with a star, are official, while others have been calculated by different officers, possibly with imperfect information as to the values of *kappa* and *sigma*.

I. RANGE TABLE FOR 15-pr. Q.F., MARK I.

This table may be taken as roughly representing the ballistics of any Krupp or Ehrhardt gun with the same muzzle velocity and weight of shell.

Charge { **Weight 15.2 oz.** / **Nature ballistite in cords.** — **Muzzle velocity 1640 f.s.** **Nature of mounting, Travelling Field.**

Projectile { **Nature Shrapnel-shell, Mark Q.F. I.** / **Weight 14lb., 6oz. fuzed.** / **2-calibre head.** — **Barometer 29 inches.**

Remaining velocity f.s.	Angle of descent, approx.	Elevation.		Range.	50 per cent of rounds should fall in—			Time of flight.
					length	br'dth	height	
		Deg.	Min.	yards.	yards.	yards.	yards.	seconds.
1475	..	..	30	500	..	...	..	0.965
1325	1 in 32	1	9	1000	30	0.15	0.86	2.043
1199	1 in 24	1	53	1500	..	..	..	3.22
1094	1 in 16	2	43	2000	32	0.3	2	4.64
1021	1 in 12	3	40	2500	..	..	..	5.97
967	1 in 9	4	42	3000	36	0.6	4	7.66
912	1 in 7	5	52	3500	..	..	..	9.3
870	1 in 5	7	12	4000	40	1.1	8	10.93
830	1 in 4	8	40	4500	..	..	..	12.71
791	1 in 3.75	10	14	5000	45	1.8	14.2	14.7
758	1 in 2.75	11	54	5500	..	..	..	16.61
721	1 in 2.25	13	44	6000	48	2.9	20.8	18.60
695	1 in 2	15	34	6500	..	..	..	20.68
668	1 in 1.75	17	26	7000	51	5.0	29	22.9

***Note.*—It is interesting to compare the accuracy figures with those of the 18pr., firing Mark I shell. The comparative inaccuracy of the German gun at short ranges is to be ascribed to the spring of the long trail; the greater accuracy at long ranges to the better shape of the shell.**

2. (From the Revue Militaire Suisse.)

	Remaining velocities in metres, and angles of descent, at							
	1000 metres		2000 metres		3000 metres		4000 metres	
	v	θ	v	θ	v	θ	v	θ
French 75mm. ...	421	1° 23′	344	3° 15′	299	7° 15′	274	11° 35′
German 96 n/A ...	369	1° 48′	310	4° 43′	279	8° 42′	256	13° 31′
Krupp 76.2 mm. ...	426	1° 19′	342	3° 42′	301	7° 6′	273	11° 30′
Krupp 75mm. ...	390	1° 34′	324	4° 17′	282	7° 57′	264	12° 30′

3. French 75 mm., calculated by Col. Deport, 1908.

Range metres:	2000	3000	4000
Angle of elevation ...	2° 39′	4° 41′	7° 16′
Angle of descent ...	3° 38′	6° 42′	10° 36′
Remaining velocity, fs. ...	1225	1065	967

It will be noted that Colonel Deport's figures give higher ballistics than those of the Revue Militaire. Colonel Deport is the more likely to be correct.

*4. Range Table for Austrian Field Gun. Calibre 76.5 mm., weight of shell 14.72 pounds, M.V. 1640 fs. or 500 metres.

Range, metres.	Elevation, degrees.	Time of flight, seconds.	Remaining velocity, metres.
500	0° 25′	1.1	428
1000	1° 12′	2.3	370
2000	3° 6′	5.3	296
3000	5° 37′	8.8	246
4000	8° 56′	13.1	210
5000	12° 56′	18.0	191
6000	17° 27′	23.2	186
7000	23° 2′	29.4	189

Note the increase of velocity at 7000 metres due to the fall from the vertex.

This shell has a forward centreing band, and is very steady in flight. A value of sigma of 0.9 appears to suit it.

5*. (Furnished by Messrs. Krupp.)

Krupp 75mm. gun, 1908.
14.3 lb. shell with 2-diameter head.

Range, metres ...	0	1000	2000	3000	4000	5000	6000
Remaining velocity, fs....	1640	1248	1043	917	830	760	700
Angle of descent ...		1/35	1/13	1/6.7	1/4.3		
Angle of opening, shrapnel		13½°	16°	17¾°	19°		

6*. (Furnished by Messrs. Schneider.)

Bulgarian Q.F. gun, 75 mm., shell 14.3 lbs. with 1.8 diameter head, M.V. 1640 fs.

Remaining velocity	1000 metres	...	1230 fs.
	2000 ,,	...	996 ,,
	3000 ,,	...	890 ,,
	4000 ,,	...	817 ,,
	5000 ,,	...	761 ,,

7. Russian 1903 gun (see Table of Field Guns.)

Remaining velocity at	0 metres	...	1930 fs.
	1000 ,,	..	1505 ,,
	2000 ,,	...	1181 ,,
	4000 ,,	...	902 ,,
	6000 ,,	...	751 ,,

These figures are not very reliable.

8. Swiss Field Gun (see Table.)

Range, yards.	0	1000	2000	3000	4000
R.V., fs.	1590	1245	1050	915	845

9.* American Field Gun (see Table.) From Journal of U.S. Artillery.

Range, yards.	0	1000	2000	3000	4000	5000
R.V., fs.	1700	1270	1038	910	837	778

10.* Argentine Gun Trials. (Official Report.)

75mm. Guns.	R.V. 35 metres.	R.V. 2000 metres.
Krupp 13.2 pr.	1665 fs.	1060 fs.
Schneider 13.2 pr.	1550 ,,	1018 ,,
Ehrhardt 14.3 pr.	1600 ,,	1004 ,,
Vickers ,,	1610 ,,	1020 ,,
Armstrong ,,	1590 ,,	1004 ,,

11. Russian 1904 3-inch mountain gun, 14.3 lb. shell.

Range, yards	0	1000	2000	3000	4000
R.V. fs.	950	875	802	733	672

12*. Dutch Krupp gun (see Table.) Official Range Table, 1907.

Range, metres	100	1000	2000	3000	4000	5000	5500
Angle of elevation ...	0	1° 15′	3° 12′	5° 48′	8° 57	12°33′	14°32′
Angle of descent ...	7′	1° 40	4° 38	8° 48′	13°57′	19°47′	23°
Time of flight, sec. ...	0.21	2.34	5.26	8.73	12.65	16.83	19.12
Remaining velocity, m/sec.	486	377	311	274	247	232	228
Breadth of 50% zone, metres	—	0.4	1.1	1.9	2.8	4	4.7
Length „ „	—	19	22	25	30	35	37
Angle of opening ...	—	7½°	9½°	11½°	12½°	13½	—

This shrapnel is evidently constructed to give a compact bullet-cone.

13*. (Supplied by the makers.)

The following ballistics of the Krupp 4.7″ howitzer have been published—

Charge	Half charge, 0.672 lbs.
Range	4265 yards
Angle of elevation	40°
Angle of descent...	45°
Length of 50% rectangle	35 yards
Breadth „ „	12.6 yards

With a full charge the rectangle is said to be much smaller.

The following figures have also been published by Messrs. Krupp:

Range.	Mean dispersion in height.	Mean dispersion in breadth.	Mean dispersion depth.
1000 yards	.9 yards	.7 yards	16 yards
2000 „	2.3 „	1.6 „	18 „
3000 „	5.3 „	3.6 „	23 „
4000 „	8.4 „	4.3 „	29 „
5000 „	17.3 „	7.0 „	41 „
6000 „	———	12.0 „	52 „

These figures multiplied by 1.69 give the dimension of the 50% rectangles.

14.* Messrs. Krupp supply the following ballistics of the 75mm. Q.F. gun, M.V. 1675 fs., shell 14.3 lbs., since adopted by Italy.

50% Rectangles, metres.

Range.	Height.	Width.	Length.	Shrapnel time fuze.	
				Height.	Length.
1000	0.6	0.5	23	1.1	34
2000	1.8	1.2	24	3.3	36
3000	4.0	2.2	28	6.7	39
4000		3.7	35	12.3	43

With mechanical time fuze these are reduced by 20°/o.

From another source:

Range at 8/100	...	1099 m.
Length of 50% rectangle		19.4 m.
Breadth ...	...	0.4 m.

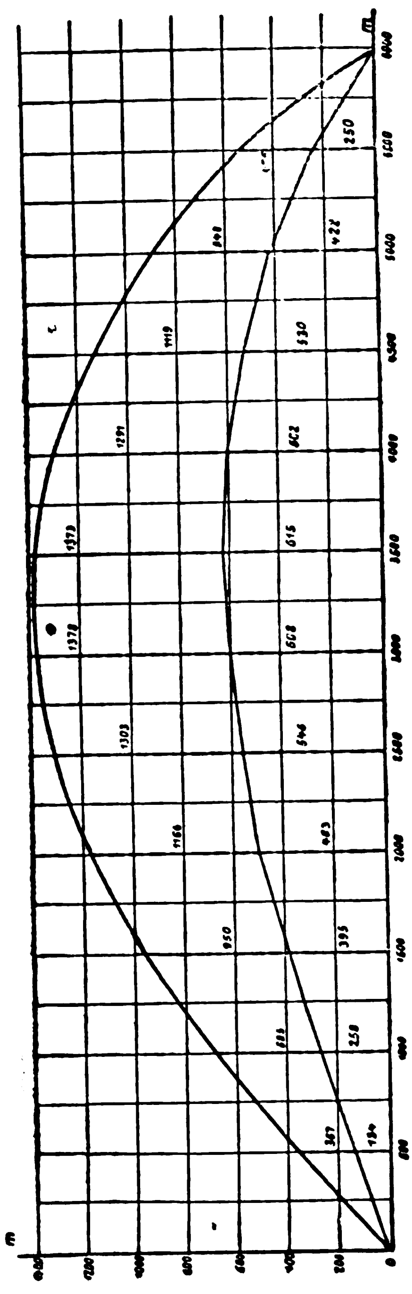
15. Italian 7 cm. mountain gun, 10.67 lb. shell.

Range, yards	0	1000	2000	3000	4000
R.V. fs.	1150	982	883	810	750

16. From Artilleristiche Monatschafte, 4.09.

The annexed diagram represents the trajectories of the Krupp 2.95″ field gun and 4.7″ howitzer at 6,000 metres. The ordinates are:

Range.	1000	2000	3000	4000	5000	metres
75 mm. Gun	275	483	608	602	422	} metres
12 cm. Howitzer	685	1166	1378	1291	847	



Part V.

GUNNERY CALCULATIONS.

CHAPTER XXXVII.

GUNNERY CALCULATIONS.

On the Use of the Plotting Chart.

Much labour may be saved in Artillery calculations by the use of simple graphical methods. Suppose, for instance, that it is required to construct a range table for the 13-pr. Q.F. gun firing a 14½ lb. shell. Instead of calculating elevations, remaining velocities, etc., for each 100 yards, we work out the figures for 1000 yards, 2000 yards, and so on, plot the results on a chart, and with the assistance of a flexible cane or "spline" we draw a curve passing through all the points plotted. For this curve we obtain by simple direct measurement the figures for every hundred yards of range.

Thus, in the above instance, take a sheet of paper say 18″ wide by 24″ high. Near the bottom of it rule a line 14″ long, marked off into 2-inch divisions; then each 2-inch mark stands for 1000 yards, and the whole line for 7000 yards. At the right-hand end erect a perpendicular 15″ high, divided into 30 parts, and let each part stand for one second; at the left-hand end erect a perpendicular 20″ high, and let each inch stand for one degree of elevation.

To make out the table of elevation, calculate by Table X of the Text Book, or Table VIII of the 1909 tables, the elevation for 1000 yards, which we find is 1° 27′, or 1.45°; make a dot on the chart 1.45″ above the 1000-yard mark on the bottom line. For 2000 yards the elevation is 3 degrees 15 minutes; make a dot 3.25° above the 2000-yards mark on the bottom line, and so on. Drive a pin into each dot, and press a flexible cane against the pins till it touches all of them; then draw a curve passing through all the dots. To find the elevation for any range we have only to measure from the curve down to the bottom line. Thus at 5200 yards the curve is 12.5″ above the bottom line, therefore the elevation for 5200 yards is 12.5″ degrees.

The curves for the time of flight, remaining velocity, and angle of descent may be drawn in similar fashion.

Even when a number of results have to be determined by calculation, it is useful to plot them. Any accidental error in a figure will then be shown up by an irregularity in the curve.

The plotting chart is useful at annual practice for working out a reliable fuze scale. This is especially the case when a new mark of fuze is issued for practice, as the official scale is frequently found to require modification.

The method is as follows—Whenever the practice report shows that the range was found within 25 yards, and the effect shows that the fuze was a good one, the fuze is accepted as correct for the range and plotted on the chart, having first been corrected for a standard height of barometer. If this is done for every good fuze found by each of the batteries, then after a few days of battery practice it will be possible to draw a curve which will give the correct fuze for any intermediate range.

Similarly, if desired, the error of each of the 18 layers in each series layed by him may be plotted on curves, affording a valuable means of comparison.

The graphic method may be applied to the easy solution of questions which would otherwise require to be solved by Higher Mathematics. Thus, in the article in this book on the gun-wheel, it was required to find the depth of a segment of a 3-foot wheel which should have an area of 10 inches.

Now the formula for the area of a segment is

$$\text{Area} = \pi r^2 \frac{A}{360} - \frac{r^2}{2} \sin A$$

where A is the angle subtended by the segment at the centre of the circle. This equation is not easy to solve algebraically. But with the assistance of the plotting chart it is a simple matter.

Draw a horizontal scale of equal parts for square inches of area, and a vertical scale of equal parts for degrees of angle. Guess the required angle at 47°, and work out the area of the segment; it proves to be 14.3 sq. in. Plot this on the chart, making a dot 47 inches (or rather 7 inches, since the 40 can be omitted) over point 14.3 on the horizontal scale. Try 43°, and we get 11 sq. inches; 40° gives us 8.75 square inches. Now draw a curve through the 3 points plotted (it is nearly a straight line) and measure up from the point denoting 10 square inches to the curve. The distance is $1\frac{3}{4}$ inches; therefore the required angle is $41\frac{3}{4}$° or 41° 45′. From this the depth of the segment is found by elementary trigonometry, the equation being

$$d = r\left(1 - \text{Cos}\,\frac{41^\circ\,45'}{2}\right)$$

where r, the radius of the wheel, is 18 inches.

To a gunner with a slide-rule, a plotting-chart, and a knowledge of elementary mathematics, few artillery problems should present any difficulty.

TRIGONOMETRICAL TABLES.

In the Text Book of Gunnery, 1907, page 240, will be found a table dealing with sines, tangents, and so forth. For the benefit of officers who have forgotten their trigonometry the following elementary explanation is given. Mathematicians are warned off.

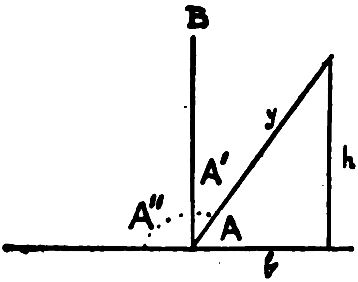


FIG. 142.

Let A be an angle contained by two lines. Let a perpendicular be dropped from any point in one line upon the other. We have then a right-angled triangle with height h, base b, and hypotenuse y. Then the fraction formed by dividing the height by the hypotenuse, h/y, is called the *sine* of the angle; the base over the hypotenuse, b/y, is the *cosine;* the height over the base, h/b, is the *tangent,* and the base over the height, b/h, is the *cotangent.* The hypotenuse over base, y/b, is the *secant,* and the hypotenuse over height, y/h, is the *cosecant.*

If a line AB be drawn at right angles to the base, then the angle A′ required to complete the right angle is called the *complement* of A. It will be obvious on inspection that the sine of an angle is equal to the cosine of its complement, tangent to cotangent, and secant to cosecant. This enables a table of sines, &c., to be simplified, the same figure standing for the sine of 30° and the cosine of 60°. Sines, tangents, and secants are read from the top of the table; cosines, cosecants, and cotangents from the bottom.

If in the figure the base be continued to the left so that the angle AA″ forms a complete half-circle, then the angle A″ is called the *supplement* of A; and its sine, cosine, &c., are the same as those of A. This is useful to remember when dealing with angles greater than a right angle. Thus if we have to find tan 105° we should look out tan 75° in the table.

The above trigonometrical tables are frequently used in artillery problems.

For instance: The calculated angle of opening of a shrapnel is 14°; what will be the lateral spread of the bullets at 100 yards from the burst?

Here AB = 100 yards: by table BC/AB = tan 7° = 0.12278: therefore BC = 0.12278 × 100 yards = 12.278 yards; therefore CC = 24.555 yards.

For angles up to 2 or 3 degrees it will be sound sufficient to use the gunner's rule, that "a minute is equal to an inch at 100 yards." Thus 35 min. subtends 35 in. at 100 yards, 40 in. at 120 yards, and 400 in. at 1200 yards. This is expressed in the rule for correcting deflection by the formula "Reduce the error to inches and divide by the number of hundreds of yards in the range," thus an error of 6 ft. right at 2400 yards requires $\frac{6 \times 12}{24} = 3$ minutes left deflection.

MENSURATION.

Solution of Triangles.

This is a problem which frequently occurs in practical gunnery calculations.

When two angles are known, the third is also known, since the three angles of a triangle are together equal to 180 degrees. And if one side is known, either adjoining side can be found, since sides are proportional to the sines of the angles opposite to them. Thus in a triangle ABC:

If the angle A be 20°, and B 85°, then C = 180 — 105 = 75°; if the side AC be 100 feet long, then $\frac{AB}{AC} = \frac{\sin C}{\sin B} = \frac{9659}{9662} = .9694$; then AB = .9694 × 100 feet = 96.94 feet.

If two sides and the included angle be known, the simplest way is to divide the triangle into two right-angled triangles.

In a triangle ABC drop a perpendicular BD upon the base AC. Suppose we know A, AB, and AC; then in the left-hand triangle we know all three angles and the side AB, which enables us to find BE and AD; hence we know DC. Then the square on BC is equal to the sum of the squares on BD and DC, which gives us BC, and the triangle is solved.

To find the angles of a triangle, having given the sides, the shortest way is to draw it.

The area of a triangle is equal to the base multiplied by half the height; thus the triangles A and B are of equal area.

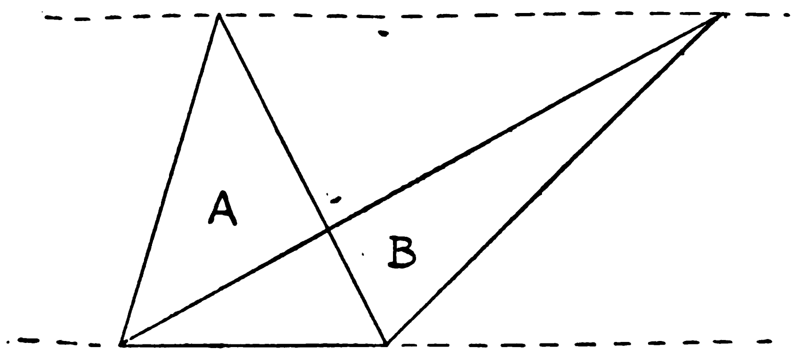


FIG. 143.

Rectilinear Figures.

The area of any plane rectilinear figure may be obtained graphically by dividing it into triangles and rectangles, as ABC, Fig. 144, or by reducing it to one triangle, as in Fig. 145, working on the principle that any two triangles on the same base and between the same parallels are equal.

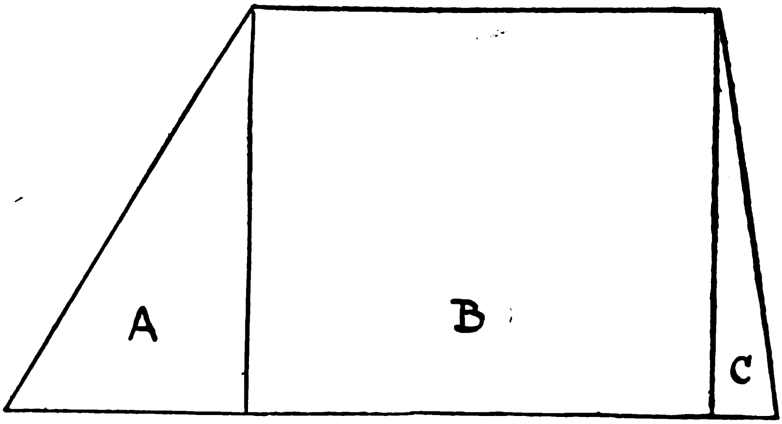


FIG. 144.

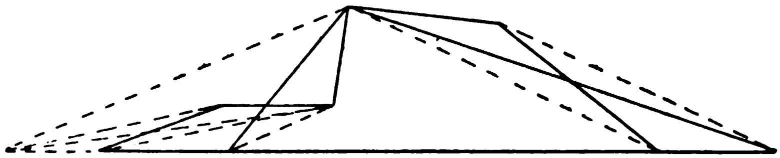


Fig. 145.

Circle.

Let r be the radius; then

Circumference $= 2\pi r$

Area $= \pi r^2$

$$\text{where } \pi = 3.14159 \text{ or } \frac{22}{7}.$$

$$\text{Log } \pi = .4971496: \log \frac{1}{\pi} = \bar{1}.5021508.$$

Sector of Circle.

Let A be the number of degrees which the arc subtends at the centre:

$$\text{Then length of arc} = \frac{\pi r A}{180}$$

$$\text{Area of sector} = \tfrac{1}{2} \text{ arc} \times \text{radius}$$

$$= \frac{\pi r^2 \times A}{360}$$

Segment of Circle.

Area = area of sector − area of triangle.

$$= \frac{\pi r^2 A}{360} - \frac{r^2 \sin A}{2}$$

Where H is the height, and B the base, then for a flat segment:

$$\text{Length of arc} = B + \frac{8H^2}{3B}$$

Cylinder.

$$\text{Volume} = \text{area of base} \times \text{perpendicular height}$$
$$= h \times \pi r^2$$

Cone.

$$\text{Volume} = 1/3 \text{ circumscribing cylinder}$$
$$= 1/3\, h \times \pi r^2$$

Pyramid.

$$\text{Volume} = 1/3 \text{ circumscribing prism}$$
$$= 1/3 \text{ are of base} \times \text{height.}$$

Sphere.

$$\text{Volume} = 2/3 \text{ circumscribing cylinder}$$
$$= 2/3 \times 2r \times \pi r^2$$
$$= 4/3 \pi r^3$$
$$\text{Surface} = 4\pi r^2$$

USE OF FOUR-FIGURE LOGARITHMS.

To find the log of a number.

Open the Four-Figure Log Table, and look up the first two figures of the number in the first column, and the third figure in the columns 1 to 9 which follow; to the log there found add the difference for the fourth figure taken from the columns 1 to 9 on the right of the table. This is the decimal part of the log; for the integral part set down the number of integral figures in the number, less one.

Thus the integral part of the log of a number is—

Number 1	... ...	...	0
Number between	1 and 10	...	0
„ „	10 and 100	...	1
„ „	100 and 1000	...	2
„ „	1000 and 10,000	...	3
	and so on.		
Number between	1 and 0.1	...	$\bar{1}$
„ „	0.1 and 0.01	...	$\bar{2}$
„ „	0.01 and 0.001	..	$\bar{3}$
	and so on.		

Remember that the decimal part of a log is always positive, though the integral part may be negative; for this reason the minus sign is put over the integral part instead of in front of the whole log.

Example—Log 1728 = 3.2375; log 6 = .7782;

log 15 = 1.1761; log 0.3 = $\bar{1}.4771$; log 0.456 = $\bar{1}.6590$;

log 0.0047 = $\bar{3}.6721$.

To multiply two numbers, add their logs. Thus log (1783 × 36.41)

$$\begin{array}{r} 3.2511 \\ 1.5612 \\ \hline = 4.8123 \end{array}$$

Now in the table of numbers to logs look up .812, and add difference for 3, making 6491; since the integral part of the log is 4, the number is in tens of thousands; therefore the result is 64910. The correct product by multiplication is 64919.03, which gives some idea of the amount of accuracy to be expected when using four-figure logs. For accurate work, Chambers' table of seven-figure logs should be used.

Similarly, 349 × .0043 = 1.501

$$\begin{array}{r} 2.5428 \\ \bar{3}.6335 \\ \hline 0.1764 \end{array}$$

To divide one number by another, substract the log of the divisor from that of the dividend—

$$\frac{348}{5312} = .05428 \qquad \begin{array}{r} 2.5416 \\ 3.8070 \\ \hline \bar{2}.7346 \end{array}$$

Beginners often find some difficulty in subtracting the log of a decimal less than unity; this can be overcome by remembering the algebraical rule, "change the sign of the divisor and add."

$$\text{Thus } \frac{146}{.0023} = 63490 \qquad \begin{array}{r} 2.1644 \\ \bar{3}.3617 \\ \hline 4.8027 \end{array}$$

To square or cube a number, multiply the log by 2 or 3; to find the square or cube root, divide by 2 or 3.

Thus $321^2 = 102800$

$\sqrt[3]{480} = 7.829$

$\sqrt[2]{.0035} = .05916$

$$\begin{array}{r} 2.5065 \\ 2.5065 \\ \hline 5.0120 \end{array}$$

$$3\,\underline{)\,2.6812} \qquad .8937$$

$$2\,\underline{)\,\bar{3}.5441} \qquad \bar{2}.7720$$

This last is a tricky piece of arithmetic, and the division is most easily accomplished by writing the log in two parts, $\bar{4} + 1.5441$, and adding the results together after division, making $\bar{2}.7720$.

THE SLIDE RULE.

This instrument enables calculations to be performed with about the same degree of accuracy as the table of four-figure logs. It is quicker to use, and certainly less fatiguing and less liable to error. Some very clear instructions for its use are contained in an article entitled Logarithmic Slide Rules, by Colonel Von Donop, R.A., in the R.A. Journal, No. 2, Vol. XXVI. This article is published in pamphlet form by the R.A. Institution.

The best slide-rule I have met with is Colonel Anderson's 12-inch rule. This has 4 parallel scales on each limb, making it equivalent to a rule 48 inches long. It is sold by Casella & Co., Rochester Row, Westminster.

APPENDIX.

THE EVOLUTION OF A FIELD GUN.

Reprinted from the Journal of the Royal Artillery.

This Essay is intended as an illustration of the practical application of the Principles of Construction enunciated in this book.

NOTE BY THE AUTHOR.

The gun described in the following pages was designed in 1904. The article is now re-printed because it illustrates the difficulties which have to be met, and the problems which have to be solved, in the design of a Q.F. field gun.

Having regard to the increase of the power of gun and rifle which has taken place within the last six years, the writer does not consider the 1904 design sufficiently powerful for modern requirements. To deal with infantry advancing in successive lines in modern extended formation, we require a gun with a flat trajectory and deep zone of shrapnel effect. Such a gun does not depend for fire effect upon accurate ranging, which is only possible at a standing target.

On the same principle, modern rifles are provided with the new pointed bullets, which shoot practically point blank up to 500 yards, and minimise the effect of inevitable errors in judging distance at longer ranges. Further, since shielded guns can be worked almost with immunity under shrapnel fire, other than that of howitzers, we must have an accurate weapon capable of making direct hits upon them with certainty whenever they expose themselves at medium ranges.

These conditions can only be fulfilled by a high-velocity gun.

The author would therefore be disposed to modify the design as follows:

1. The gun to be 35 calibres long, giving a M.V. of 2000 fs., firing a 16 lb. shell with 3-calibre head.

2. The weight in action, with shield, not to exceed 24 cwt.

3. Steadiness to be obtained by using 4′ 4″ wheels, as in Continental equipments, and by cranking the axletree 3″ downwards. This, with careful design, should still allow 18″ of clearance under the carriage.

4. The elevating gear to give only 10° of elevation, which, with a 3-diameter head to the shell, will carry the shell nearly 7000 yards. This reduced range of elevation would allow a plain central double screw to be used, instead of the complicated worm wheel gear which was a weak point in the 1904 design.

5. The gun to traverse on the axletree. This avoids the complications of the pivoted cradle or upper carriage, and modern experience shows that this gear is fully efficient.

6. The springs to be replaced by compressed air as in the Schneider and modern Armstrong equipments. Experience has demonstrated the serviceability of this gear, and there is no doubt that the carriage is quieter and more free from vibration, giving better shooting than when springs are employed.

6. In view of the necessity for accurate fire at shielded guns, a reciprocating sight is required. The best pattern for use with the independent line of sight is Colonel Scott's automatic sight, with a panorama attachment for all-round laying.

7. The limber to carry 24 rounds only, and to weigh 12 cwt., making the weight behind the team 36 cwt. Spring draught and spring limber hooks to be fitted, and all ammunition boxes to be on springs.

There is one drawback to the proposed high-velocity gun, and that is the difficulty in finding a covered position for it, on account of the flatness of its trajectory. This might be overcome by making the fixed ammunition separable, as in some of the Krupp equipments, so that, if it were desired to come into action in a deep hollow, a portion of the charge might be withdrawn. This would of course necessitate a second range table and fuze scale. But this extra complication is a minor matter compared to the greatly increased efficiency of the gun.

H. A. B.

Woolwich, January 1910.

APPENDIX.

THE EVOLUTION OF A FIELD GUN.

(1904.)

From time immemorial it has been the privilege of the regimental officer to grumble at the *matériel* supplied to him. No doubt the Greeks before Troy complained of the short range of the catapults and freely criticised the legs of the wooden horse.

Now sound criticism from the regimental officer is an excellent thing. It is only by correcting our shortcomings that we can make any progress towards perfection, and the gun-designer must always look to the practical gunner to point out the defects in his design.

If the regimental officers were all of the same opinion as regards the alterations and improvements to be carried out, the task of the designing and manufacturing departments would be comparatively easy. Unfortunately, however, a plébiscite of the Royal Regiment is apt to give rather vague and contradictory results It is not so much that officers differ as to tactical requirements, but that the main issues are obscured by a mist of technical difficulties. This is especially the case as regards Q.F. field guns. Most officers at home have had an opportunity of seeing and handling modern guns; but for officers abroad the only means of keeping their knowledge up to date is the study of the occasional translations from foreign magazines which are published with the Journal of the Royal Artillery.

Moreover, the theory of construction of modern Q.F. guns, carriages and ammunition is a new science. No books have hitherto been written on the subject, and the rules of construction applicable to the older guns require considerable modification to bring them up to the level of modern science.

It is therefore not a matter for surprise that a large proportion of regimental officers have rather a vague idea of the construction of a Q.F. gun, of the qualities to be aimed at by the designer, and of the practical limitations by which designer and manufacturer are bound.

It may assist officers to form more definite views upon these points if we follow the design of an imaginary field gun, considering the difficulties of construction as they arise, and describing the methods devised by modern science to overcome these difficulties.

In dealing with such a subject it is difficult to avoid the temptation to attempt originality—to try for something never thought of before, which shall throw all previous inventions into the shade. But practical experience shows that such flights of imagination do not advance one very far. It is only once in a century that a genius like Marconi arises to upset all our preconceived notions of things possible. Improvements in guns and gunnery have so far been due to the gradual development and perfection of existing types,

Moreover, even supposing it possible to originate a novel design of surpassing excellence, it would be open to the *primâ facie* objection that no one could predict whether the gun would work or not till it had been practically tried.

It is proposed, then, to keep strictly to the beaten track, and to describe an imaginary equipment of which every individual feature has already been practically tested and approved.

SPECIFICATION.

Let us suppose this, such as to give the designer a free hand, and that the problem is merely to produce a powerful Q.F. gun of moderate weight. Then the easiest method will be to begin by designing a gun of sufficient power, then to calculate its weight, and finally, if necessary, to modify the design in order to bring the weight down to a practical figure.

THE CALIBRE.

For a given weight of shell, the smaller the calibre the higher will be the ballistic coefficient. But, on the other hand, the longer the shell the less will be the useful weight, *i.e.*, the proportion of the weight of the bullets to the total weight of the shell. And since after all a gun is merely a machine for delivering bullets at a given distant point, this last consideration is of great importance.

The choice of the calibre must therefore be of the nature of a compromise. There is a considerable weight of scientific opinion in favour of a 2.75″ calibre—the size originally proposed by General Wille in his "Field Gun of the Future"—but no successful 2.75″ gun has yet appeared, and all the Continental nations, besides America, have adopted a gun of about 75 mm. or 3″ calibre. We shall therefore be quite safe in accepting 3 inches as the calibre of our gun.

WEIGHT OF SHELL.

This is a comparatively simple matter; most modern 3″ guns have shrapnel weighing 14.3 to 14.7 lbs., and the American shrapnel weighs 15 lbs. The latter size gives a better shrapnel and better ballistics than the two former, but the recoil is necessarily greater. As however we do not propose to limit ourselves so strictly in the matter of weight as the modern German manufacturers, we may start with a 15-lb. shrapnel, subject to a possible reduction should the recoil prove too much for our carriage.

MUZZLE VELOCITY.

The object of a high muzzle velocity is not to increase the range of the gun, nor yet the remaining velocity; it is to decrease the angle of descent. The steeper the angle of descent, the less the distance which the shrapnel bullets will cover before they are stopped by striking the ground. Modern infantry tactics, and the Q.F. artillery tactics which have been devised to meet them, require the power of covering a large area with bullets without sacrificing intensity of effect; and this is most economically achieved by increasing the effective depth of the shrapnel cone without reducing the number of bullets or the angle of opening.

The French gun is a good example of a successful combination of angle of opening and angle of descent. It is reported to have a M.V. of 1740 fs. with a 15.95 lb. shell. This, with an angle of opening ot 16½°, gives at 3000 yards a cone 330 yards deep with a maximum width of 95 yards, containing some 250 (out of 300) effective bullets of 38 to the lb.

Since the ballistic coefficient of our shell will be somewhat inferior to that of the French shell, we will try a higher velocity, namely 1800 fs.

BALLISTICS.

We can now lay down the ballistic elements of our gun. Assuming a shell with 2-diameter head, we shall have a range of 6000 yards with 11° 44′ elevation, 7,600 with 18°, and 8,000 with 20° 10′. The angle of descent will be 4° 8′ at 2,500 and 7° 56′ at 3,500 yards; the angle of opening of the shrapnel at 3,500 yards will be about 17°. The muzzle energy will be 337 foot-tons.

THE GUN.

We have next to design a gun to give the required ballistics.

There are two ways of getting a high M.V. out of a gun—one is to increase the length, and the other to increase the powder charge. The former is by far the most satisfactory method, as involving less strain and less waste of powder. Let us see what precedent we can find to guide us as to the length of the gun.

The Elswick Field Battery in South Africa were equipped with the "Lady Meux" gun, 130 inches long. They took these guns throughout the war, and marched several thousand miles with them. One gun covered 2,300 miles in 15 months. No objection was ever made to the long muzzle.

On the other hand, the average length of modern guns is considerably less than this, 92 inches being about an average.

Now calculation shows that if we take the pressure in the chamber at 15 tons (the usual amount for a field gun) then to get 1,800 fs. the bore will have to be 32 calibres long, giving a total length of 102 inches. This is a moderate length and may be accepted as suitable.

This gun will require nearly 20 oz. of cordite, Mark I., size 10, occupying 82 cubic inches. Cordite burns better in a short chamber than in a long one, and if we adopt a coned chamber 4″ in diameter at the base and 10″ long, it will hold the charge comfortably.

If tubular cordite be used, the pressure in the chamber will be slightly less and the ignition possibly more regular.

WEIGHT OF GUN.

The weight of the gun may be determined by comparison with approved models. Thus the Ehrhardt 15-pr. Q.F. gun weighs 737 lbs.; add 45 lbs. for lengthening the muzzle 12 inches, and we have 782 lbs. The increase of strain due to the larger powder chamber may be met by adopting the R.G.F. wire construction instead of the simple Ehrhardt two-layer build, while the abolition of the chase rings used on the original model will enable the diameter of the gun to be increased from 8″ to 8.25″ without increase of weight.

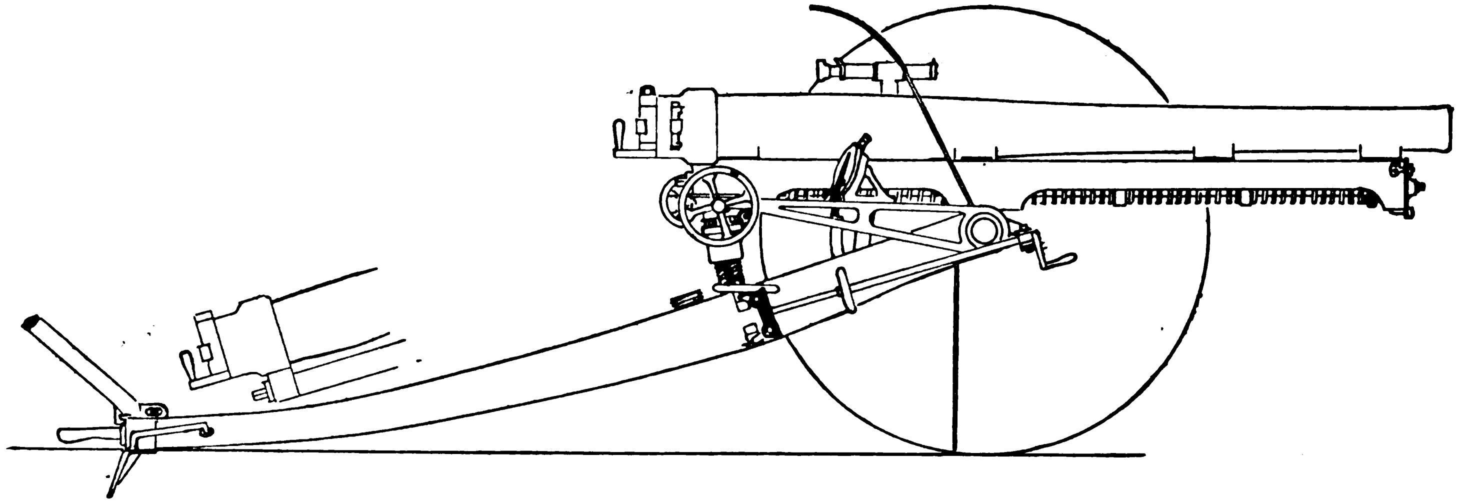


FIG. 1.

15-pr. Q.F. Gun, M.V. 1,800 fs. Scale: $\frac{1}{2}$ inch to a foot.

Fig. 1 shows the gun viewed from the right side; the support for shield is omitted to avoid confusing the drawing. The gun is intended to have a preponderance of 28 lb. Owing to the complicated shape of the parts it is difficult to calculate the exact position of the gun for a given preponderance, but the drawing is correct within an inch or so. But with a cradle affording a bearing for the gun 7′ 6″ long, considerable latitude is permissible, and the gun may be shifted three inches or even six inches either way without affecting the rest of the design.

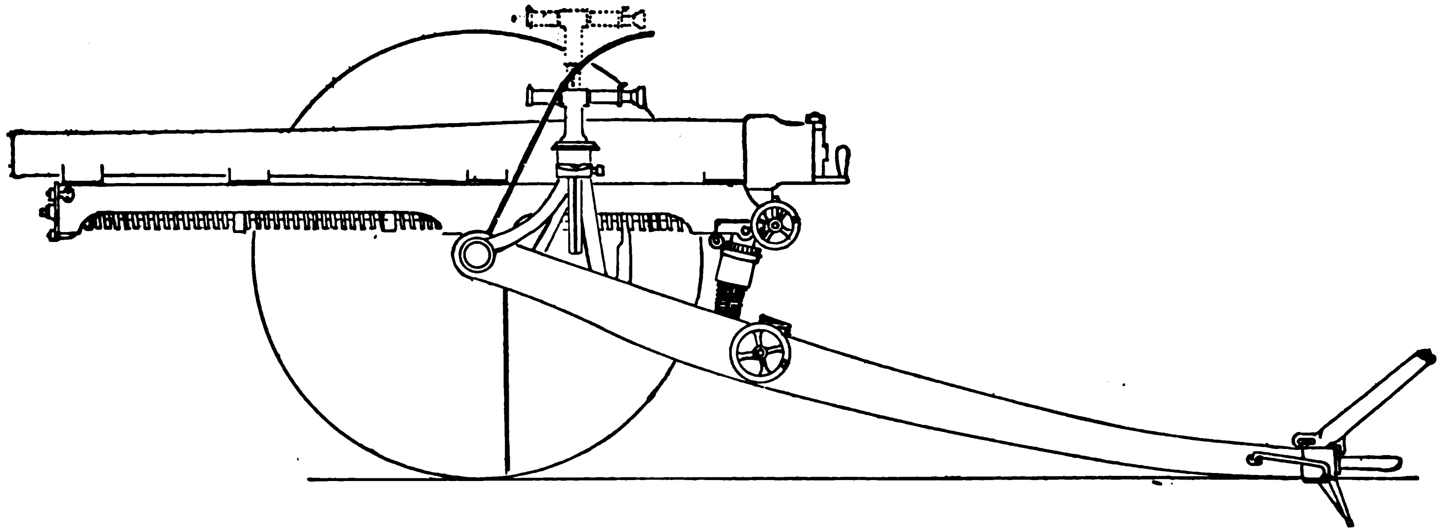


FIG. 2.

15-pr. Q.F. Gun. View from left side.

The figure shows the gun from the left side. The brake arm, seat, shield-stay, and stay connecting traversing bed with axletree are omitted for the sake of simplicity. The layer's seat is on the brake arm and is supported like a music stool upon a screw which enables the layer to adjust its height so that the telescope is convenient to his eye. The firing lever is not shewn; it is placed conveniently to the layer's left hand, and works a trigger in the face of the breech which cocks and releases the trip-lock in the breech block. If the gun fails to run up completely, the firing lever will act so long as the gun is not more than two inches short of its proper position. Under the breech is a locking catch; when the gun is at maximum elevation, with the cradle right down on the trail, this catch may be secured, locking the laying and elevating gear so as to prevent any strain upon them in travelling.

RIFLING.

The determination of the best pitch for rifling for a given shell is not yet, unfortunately, a matter of exact science. But the pitch adopted for the new American 15-pr. is one which has given excellent results, namely a twist increasing from 1 in 50 at the breech to 1 in 25 calibres at the muzzle.*

MATERIAL.

All modern guns are made of nickel steel, containing 3 to 6% of nickel, and having a tensile strength of about 50 tons to the square inch.

BREECH ACTION.

Both the wedge and the eccentric screw are simple, strong and durable. But the latest model of swinging block is more powerful in loading and extracting than either of these, and consequently less liable to jams. This action (which has been adopted in our own Q.F. equipment and in the American gun) has a single-motion cylindrical swinging breech-block. It is set about ½" eccentric to the gun, so that when the breech is closed the striker is not opposite to the cap in the cartridge till the block has been turned through a right angle to lock it. This forms an efficient safeguard against prematures occurring in closing the breech.

The firing action is a trip-lock, in which the layer, by pulling the firing lever, first draws back the striker and then releases it.

The extractor grips the cartridge both above and below, and is actuated by the breech-block, which at the end of its swing strikes the outer end of the extractor and so causes the inner end to jerk out the cartridge.

RECOIL GEAR.

The hydraulic buffer is well established as an efficient means of checking recoil. It consists of a cylinder 2.75" in outside diameter and 0.3" thick, attached by a horn to the breech of the gun. In this works a piston, the front end of the piston-rod being attached to the carriage. When the gun recoils, the cylinder is drawn back and the oil oı glycerine in the cylinder is forced to flow through the narrow space or windage between piston and cylinder, formed by the grooves or ports in the inner wall of the cylinder, thus gradually checking the recoil. The depths of these ports is slightly different at different points so as to keep the pull on the piston-rod proportional to the varying stability of the carriage throughout the recoil.

Boring a buffer for uniform stability is a delicate operation, as a difference of a couple of hundredths of an inch is found to make all the difference between a steady gun and one which kicks likes a mule. The correct depth of the ports at each point is determined by the use of the buffer gauge, first introduced by the Elswick Ordnance Company.

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*NOTE.—The 1909-10 fashions in gun-designing favour the uniform twist.

This is a pressure gauge communicating with the inside of the buffer through a hollow piston-rod, with an indicator which, as the gun recoils, traces a line on the smoked surface of a strip of metal attached to the gun. If the pressure is correctly regulated, the line is a curve parallel to the curve of stability. If it is not, the boring of the buffer must be adjusted accordingly.

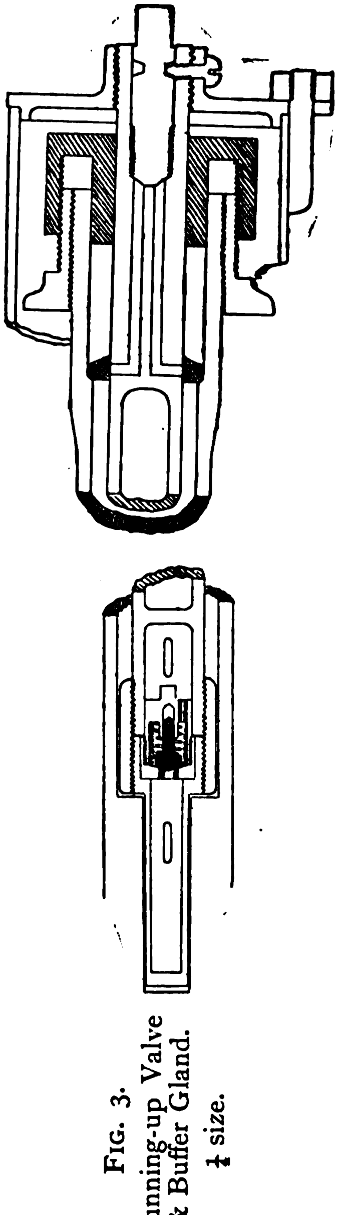


Fig. 3. Running-up Valve & Buffer Gland. $\frac{1}{4}$ size.

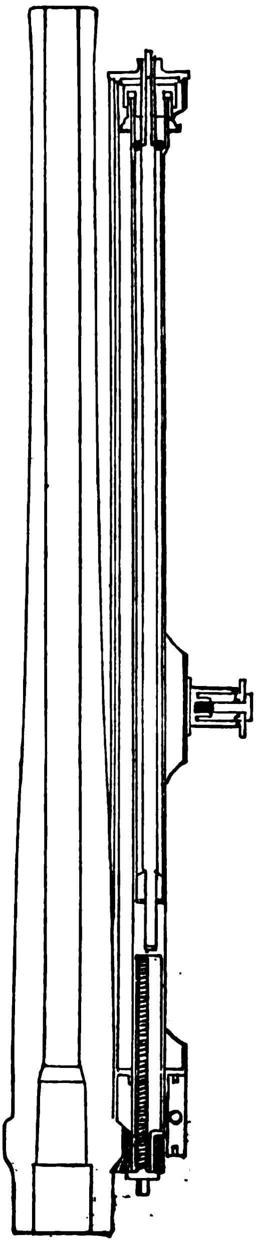


Fig. 7. Section of Gun and Buffer. Scale $\frac{3}{4}''$ to a foot.

LENGTH OF RECOIL.

Modern Continental guns have usually a working recoil of 1¼ mètre or 50 inches. As the M.V. chosen is unusually high, we may take a minimum recoil of 4 feet 6 inches, and maximum permissible recoil of 5 feet. The considerations which justify us in accepting this as sufficient will be discussed under the head of Steadiness.

DETAILS OF BUFFER.

These are shown in Figs. 3 and 7, and are mostly copied from the Krupp 1904 equipment. Attention is called to the loose bottom of the stuffing box.

BUFFER LIQUID.

Either oil or glycerine may be used, the buffer being bored to suit. The writer prefers glycerine, as, although it is more difficult to obtain on service, it is more viscous and less subject to leakage through the gland.

RUNNING-UP VALVE.

This is a speciality of Ehrhardt's. In order to make the gun run up smartly after recoil, strong springs have to be used to overcome the buffer resistance. But if a valve be inserted in the piston to allow the glycerine to pass freely during running-up, the springs may be much thinner and lighter. No details of the Ehrhardt valve are available, but a suitable arrangement is shown in Fig. 3.

A second disc-valve on the end of the piston is rotated by rifled grooves in the buffer and gradually cuts off access to the running-up valve as the gun returns towards the firing position, thus bringing it gently to a standstill.

RUNNING-UP SPRINGS.

The column of springs cannot without undue increase of weight be made more than about 6 feet 6 inches long. But if the gun is to recoil 4 feet 6 inches, this means that the springs must be compressed into a space of 2 feet each time. For some years it was believed that springs could not be made to stand this treatment, and telescopic spring-cases were used, with a double column of springs, which practically halved the compression. But it is now found that flat springs of suitable section will stand compression to one-quarter of their length (in addition to the initial compression) without injury. The light springs which the running-up valve enables us to use give no trouble in this respect.

Accordingly, in the Krupp gun we find the springs compressed to one-quarter of their length. To be on the safe side we will only require our springs to stand compression from 6 feet 6 inches to 2 feet, or about one-third of their length. This arrangement is shown in Fig 7.

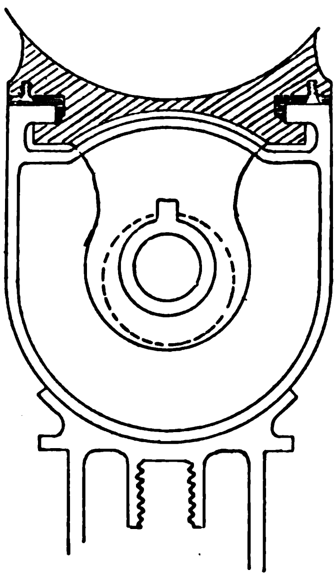
Since the buffer must be parallel to the gun whatever angle the latter makes with the main carriage, the gun and the buffer must be connected by a cradle, provided with slides for the gun and with a trunnion or trunnions which connected it to the carriage. (The only exception to this practice is found in the 1900 Russian gun, in which the buffer is parallel to the trail, not to the gun.) The buffer is sometimes placed on top of the cradle, as in the English equipments. In these guns the cradle has horizontal trunnions and is mounted on an intermediate carriage, capable of traversing horizontally upon the main carriage.

A more usual construction is to put the buffer under the gun and to mount the gun on a slide on top of the cradle. This arrangement is adopted in the French gun, the American gun and by all Continental gun-makers. The new German gun is also of this pattern. A dissertation on the relative merits of the two systems would here be out of place; but it may be said that the advocates of the carriage with buffer under the gun claim lightness, simplicity and durability for their system, while the advocates of the top buffer claim to get the gun six inches lower than is possible with the other method.

Following our plan of choosing the easiest and most frequented path, we will select the system with buffer under the gun as most suitable for our present design.

The pattern of cradle chosen is that brought out by Messrs. Ehrhardt and modified by Krupp. This is a drawn steel tube containing the buffer and springs, of the section shown in Fig. 5. The

FIG. 5.
The Cradle.



gun slides along the top edges of the cradle, steel blocks being formed on the outer tube of the gun for the purpose. These blocks are faced with bronze to reduce friction.

Messrs. Krupp, in one of their designs, modified the Ehrhardt cradle by cutting away the lower part so as to expose the springs. They claim that this not only saves weight but reduces the chance of the gear being jammed by a bullet indenting the spring-case. It is considered that a bullet striking the spring would not be likely to break it.

Traversing Gear.

In the French gun, the gun, cradle, and trail traverse together along the axletree. This plan has the advantage that the recoil is always in line with the centre of the spade, so that the carriage does not tend to shift on firing. On the other hand, the weight to be moved is considerable, and, to prevent the wheels from shifting instead of the gun when the traversing gear is worked, special brake-shoes with fins have to be used under the wheels, which means delay in coming into action or in changing target.

We need therefore have no hesitation about adopting the central pivot method. For this, when a cradle under the gun is used, the cradle is pivoted with a single vertical trunnion either in a saddle pivoted horizontally between the trail brackets, or on the axletree itself. The latter system has both advantages aud disadvantages. It means that when the gun is elevated or depressed the axletree has to turn with it, and consequently that the trail must be attached to the axletree with cap-squares, so as to allow the axletree to revolve. On the other hand, the system does away with the intermediate carriage and its trunnions, and allows the traversing bed to be rigidly connected to the axletree, giving a strong and simple construction. The actual traversing gear is quite simple, consisting of a hand-wheel and worm at the rear end of the cradle, gearing with a toothed segment formed on the traversing-bed, and allowing a traverse of 5° either way.

The Wheels.

Here we have an excellent pattern ready to hand in the Woolwich double-spoked 35B pattern, which has been thoroughly tested in South Africa. The diameter of the wheel is however a matter requiring consideration. The lower the wheel, the shorter the trail and the less the weight of the gun-carriage. On the other hand, small wheels mean heavy draught and reduced freedom of movement across country.

Most foreign equipments have 4 ft. 3 in. wheels; the American wheel is 4 ft. 8 in. English gunners have hitherto been accustomed to 5 ft. wheels. For the purpose of the present design, we may compromise on the 4 ft. 8 in. wheel, with the reservation that if we resulting weight of the carriage turns out to be excessive we shall have to reduce the size of the wheel.

The Trail.

The French gun, which is perfectly steady on discharge, has a trail angle of 1 in 4. This, with a wheel of 2′ 4″ radius, would make our trail 9′ 4″ long. As however we hope to get the gun lower on the carriage than the French gun, we may try a somewhat shorter trail,

namely 9 ft. on the ground line. This is about the same as the Krupp trail, but a good deal short of the length considered necessary by Ehrhardt and by the Americans, who use a 10′ 6″ trail.

The profile of the trail is such as to give 1″ clearance under the gun at full recoil and at the maximum elevation, 17°. This necessitates the trail being bent at the lower end. This feature may be noticed in several guns, as in the Cockerill and St. Chamond equipments. The trail is formed as a U-shaped trough of 0.25″ steel plate with the upper edges turned in; the rear portion is stiffened by a light steel top-plate, and there is a sole plate to protect it from injury on hard ground. The trail is open top and bottom forward of the elevating gear, where it is strengthened by a ring forging at top, which also carries the guides for the laying block. Forward of this the trail forms two brackets, which are splayed 14 inches apart so as to allow the arm carrying the telescope, and the arc which controls the range-dial, to clear the gun at maximum traverse. The brackets are attached to the axletree by capsquares as in the Ehrhardt equipment.

Steadiness.

We can now consider whether the proposed gun will be steady on discharge. The calculation of the overturning strain is not quite a simple matter, being complicated by cross strains in the carriage. Broadly speaking, the higher the axis of the gun the greater will be the overturning moment. The position of the point of attachment of the buffer to the carriage has considerable influence on the result. But in this case, since the buffer is below the gun, we shall have something in hand if we take the overturning strain as acting through the axis of the gun. For with the buffer under the gun, the centre of gravity of the recoiling parts, through which the force of recoil must be assumed to act, is below the axis of the gun.

Assume that the whole system pivots about the centre of the spade, 3″ below the ground line. Then on the one hand we shall have the force of recoil acting through the axis of the gun, and tending to turn the gun over backwards; on the other hand the weight of the gun and carriage acting through the centre of gravity and tending to keep the wheels on the ground.

Now the M.V. being 1800 fs. and weight of shell 15 lbs., the muzzle energy in foot-lbs. is:—

$$\frac{15 \times 1800^2}{2 \times 32.2}$$

or 337 foot-tons.

The weight of the gun is 782 lbs.; weight of buffer (which recoils with it) 79 lbs., and half the weight of springs 35 lbs., total 896 lbs. The weight of the shell is 15 lbs., that of the charge 20 oz.

The ordinary recoil formula is:—

$$WU = (w + Cw_1)\ V$$

where C, the coefficfent for the increase of recoil due to muzzle blast, is taken at $1\frac{1}{2}$. Putting the above values in the formula, we get: —

$$U = 33{\cdot}0 \text{ fs.}$$

whence the recoil energy is :—

$$\frac{896 \times 33.9^2}{2g \times 2240}$$

or 7.142 foot-tons.

Since the recoil-energy is absorbed during a recoil of $4\frac{1}{2}$ feet, we have an average pull on the buffer-rod of :—

$$\frac{7.142}{4.5} \text{ tons.}$$

or 1.587 tons.

The height of the axis being 41 inches, or 44 inches above the centre of the spade, we have, when the gun is fired without elevation, a force of 1.587 tons acting at the end of a 44-inch lever tending to overturn it. This force is resisted by the weight of the gun and carriage, which we may estimate provisionally at one ton, acting through the centre of gravity about 7′ 6″.*

Then we have an overturning force of

$$\frac{1.587 \times 20 \times 44}{12} = 116.4 \text{ cwt.}$$

against

$$1 \times 7.5 \times 20 = 150 \text{ cwt.}$$

Therefore, assuming the boring of the buffer to be perfect, we have some stability in hand even when firing without elevation. As the elevation is increased the leverage of the gun decreases and the stability increases, so that a well-designed carriage tends to "squat" or sink into the ground at each shot.

The above calculation does not take into account the elastic rebound of the carriage, due principally to the spring of the trail under the pressure of the elevating screw. In modern Continental equipments it is customary to allow 5 cwt. or 6 cwt. of surplus steadying weight on this account. We have only allowed

$$\frac{150 - 116}{7.5}$$

or 4.5 cwt. But it should be said that, in Germany especially, there is a tendency rather to exaggerate steadiness at the expense of power. The cult of steadiness has degenerated towards a rather flat-catching form of advertisement, and German makers proudly announce that their gun will put 12 rounds of rapid fire into a target without relaying. This is all very well, but the Battery Commander does not want to fire his guns without re-laying, except at "Cavalry attack." It is sufficient for practical purposes if the deviation is so slight that the layer is able to correct it during the time available—say three seconds—between the rounds.

* The calculation is not really so simple as this, since the centre of gravity shifts as the gun recoils, and the buffer-resistance has to be adjusted accordingly. But for a preliminary estimate it is sufficient to take the mean position of the centre ot gravity. Strictly speaking, instead of the height of the axis we should take the height of the centre of gravity of the recoiling parts.

We may take it, then, that the present design will fulfil practical requirements as to steadiness. To obtain a higher degree of steadiness with the proposed muzzle-energy we must either increase the weight of the gun, or reduce the of the wheels, or increase the length of the trail. And none of these three alternatives commends itself to the regimental officer.

LAYING AND ELEVATING GEAR.

No modern Q.F. gun is complete without the "independent line of sight." This means that the laying number works a wheel which elevates the gun and sights together till the sights bear on the target, while the elevating number, on the other side of the gun, works another wheel which gives the gun the elevation above the line of sight required for the range, without affecting the sights. The amount of elevation given is shown on a drum.

This arrangement greatly facilitates the service of the gun, and we need have no hesitation in embodying it in the present design.

RANGE OF ELEVATION.

The long-trail equipments at present in existence, as the Ehrhardt and the American guns, have one serious disadvantage, namely the limited amount of elevation that can be given. This works out as follows:

Suppose the gun brought into action on a 3° forward slope, at a target 3° above the battery. Then for the first round, before the spade has sunk into the ground, the point of the trail will be another 3° above the normal level, making a total deduction of 9° from the elevation allowed by the carriage. That is, if the carriage affords no more than 15° of elevation, we shall only be able to put on 6° for the first round. This evil is reduced in the present design by the increased muzzle velocity, which requires less elevation of a given range. But even so the usual 15° is insufficient, and provision is therefore made for giving 17°. This, in the above combination of unfavourable circumstances, will still give a possible elevation of 8° or 4,800 yards nearly for the first round.*

No depression is required, since the gun is never depressed below the line of sight. If the target is below the battery the necessary depression is given by the laying gear, not by the elevating gear.

With the laying gear we require to point the sights at a target 3° above the battery, when the gun is on a forward slope of 3°, and before the spade has sunk in. We may also require to point the sights at a target of 3° below the battery, from a reverse slope of 5°. Therefore we shall require a range of at least 17° from the laying gear.

* The Japanese field gun, which was built for rough mountain country, has a range of elevation and depression of 25 degrees.

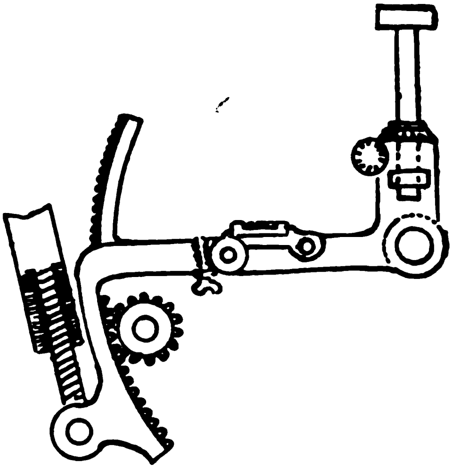


Fig. 9.
French Gear.

The principle of the laying and elevating gear is adapted from the French gear, which, apart from the traversing arrangement, has proved a conspicuous success. Part of the French gear is shown in Fig. 9, and it will be seen that the gear sketched in Fig. 10 is on the same principle. The French gear consists of a radius bar which carries the sight standard and clinometer, pivoted on the same centre as the trunnions of the cradle. The rear end of the bar is raised and lowered by a pinion worked by the laying wheel, which gears into a toothed arc on the bar. The elevating screw is stepped at the rear end of the bar, which thus answers the purpose of an intermediate carriage.

Now, when we attempt to use this device in our design, we find that a toothed arc of 17° sticks out either above the trail, where it would foul the gun during recoil at extreme elevation, or below the trail, where it would be smashed in driving over a bank. We must have something more compact. Mechanical science affords many ways of effecting this; the one preferred is sketched in Fig. 10 and shown in detail in Fig. 4.

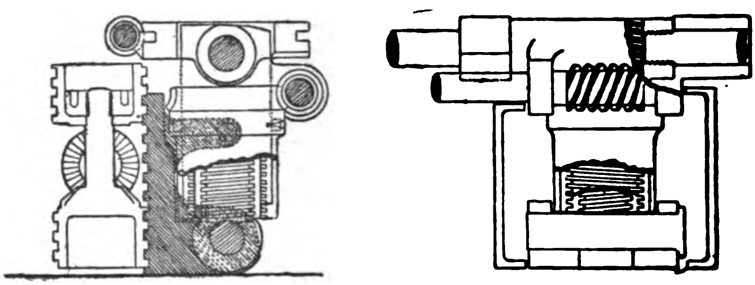


FIG. 4.
Laying Screw and Elevating Screw.—1/8 Size.

Fig. 4 shews the laying and elevating screws. The double elevating screw screws into a socket which supports the traversing bed, and so the rear end of the cradle. This is the same as the French arrangement, except that the latter has no traversing bed. The outer screw is turned by a sheath surrounding the socket, with two projections which engage in longitudinal slots cut in the outer screw, as in the 15-pr. B.L. elevating gear. The sheath is held in place by a ring sprung into a recess in the sheath and screwed (through a hole in the sheath) to the socket. The sheath is turned by a triple-threaded worm; the worm-shaft is revolved by a pinion gearing with an inside-toothed wheel at the back of the elevating wheel. A more direct

gear would be a pair of bevel wheels instead of the worm. But to get 17° of elevation we have to use every inch of space between the breech and the trail, and it is not easy to find room for a pair of bevel wheels. Room might be made by bending the trail downwards, but this means either loss of rigidity or increased weight.*

In Fig. 10 we have a block, known as the laying block, working in guides between the trail brackets, moved up and down by a screw

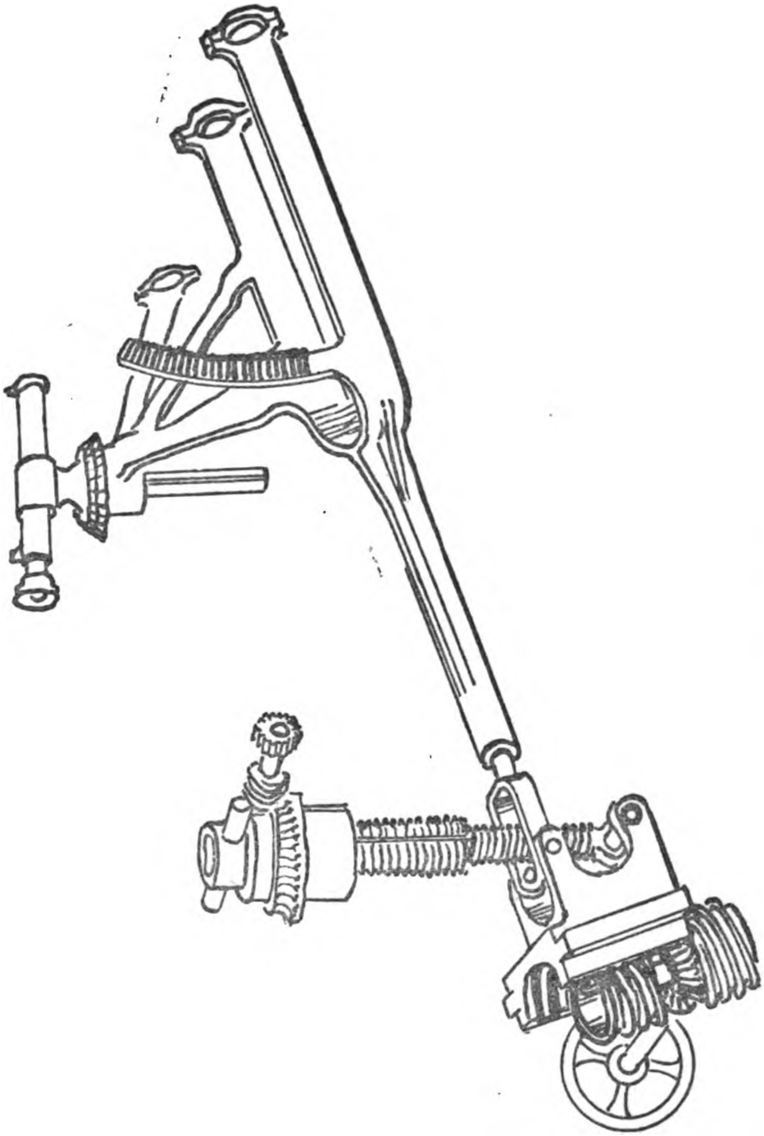


FIG. 10.
Sketch of Laying and Elevating Gear.

* NOTE.—On re-consideration, the author would prefer a bent trail and a simple elevating gear. (1907.)

which engages with its rear face. The screw is hollow, 4 inches in diameter, and 8½ in. long, which gives us room to cut away 3½ inches in the centre for a pair of 3" mitre wheels to turn it, and still have 2½ inches of screw engaging with the block in the extreme highest and lowest positions.

The rear end of the radius bar is pivoted to the block. But since the bar moves in an arc and the block in a straight line, the joint between them must allow of a small amount of longitudinal movement. At first sight this might appear to introduce an error in elevation, since the block does not move through quite the same angle as the gun. But this error is eliminated, as will be seen afterwards.

The radius bar is of steel, of such a form as to be as rigid as possible in a vertiical plane. Its front end embraces the axletree on either side of the vertical trunnion. It is not however pivoted directly upon the axletree, but upon a bronze sleeve on each side, surrounding the axletree and tightly gripped by the trail, so as to turn with the trail. The effect of this is that the accuracy of the pivoting is not affected by wear between axletree and radius bar, and the extent of motion of the joint is limited to that between radius bar and trail, which is only that due to the angle of sight. Moreover the telescope is saved from direct shock due to the vibration of the axletree in travelling.

The radius bar carries the telescopic standard on one side, and the toothed arc which works the elevating dial on the other. Owing to the small space left by the traverse of the gun, it is only possible (without unduly increasing the width of the trail) to make the pedestal rigid in a fore-and-aft direction. Lateral rigidity has to be provided by a side stay pivoted on an extension of the axletree sleeve already referred to. *See* Fig. 15.

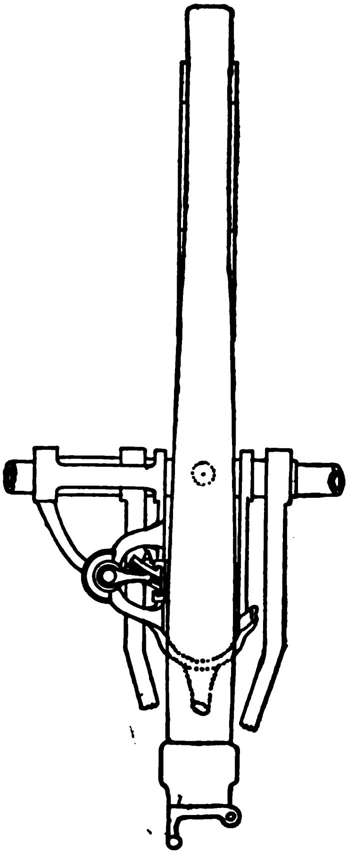
Traverse of Sights.

In the French equipment, when the gun is traversed, the trail, cradle and sights move with it. But in the present design we have discarded this feature, and the traversing gear is applied to the gun itself, not to the trail.

It is therefore necessary to provide some arrangement for making the sights traverse with the gun. For the sights and the gun must move together, in order that the gun may always point in the same direction (barring deflection) as the sights.

In one of the Ehrhardt field howitzer equipments this motion is provided for by connecting the vertical pivot of the sight bar to the vertical trunnion of the cradle by a bicycle chain, so that sight and howitzer revolve together through equal angles. Several other mechanical devices may be used for the same purpose, such as the connecting rod, or crossed links. But probably the simplest and most compact gear is that shown in Fig. 15.

The telescope socket, which carries the divided circle and the telescope with its base-plate, is capable of revolving in the pedestal. An arm project from the socket towards the gun, terminating in a roller working in a cam-groove in the traversing plate *A*. This plate traverses right and left with the gun, and the cam groove is so cut that as the plate traverses it moves the arm, and so the telescope, through the same angle as the gun. The traversing plate is supported in a guide carried by the radius bar, which also carries the telescope pedestal.



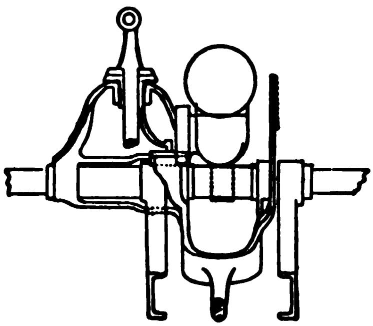


FIG. 15.
Sight Traversing Gear.

To enable the gun to be elevated and depressed freely without affecting the traversing plate, the latter is not rigidly attached to the gun or cradle but works in a circular guide on the side of the cradle, struck from the centre of the axletree.

THE ELEVATING GEAR.

This is of the familiar double-screw pattern. The inner screw is stepped on a pivot in the laying block; it is surrounded by the outer screw, which again screws into the socket pivoted to the traversing

platform. The outer screw is slotted to receive two projections on the lower ledge of the sheath which surrounds the socket, so that when the sheath is turned by a worm wheel the outer screw is rotated, screwing itself off the inner screw and out of the socket simultaneously.

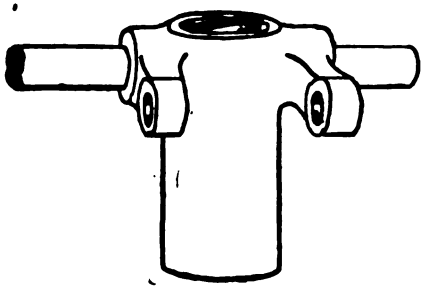


Fig. 8.
Sketch of Elevating Screw Socket.

No part of the gear may project below the trail, so the space into which the screws must pack is limited. To make the most of the space, both screws are carried up right through the socket, which again goes up through the centre of the traversing platform; and the traversing platform itself is bedded not under the rear of the spring-case, but close up under the buffer. This arrangement shortens the spring-case by 3½ inches at the rear end, which amount has to be added at the fore-end of the cradle; but this drawback may be put up with for the sake of keeping all the gear above the level of the bottom of the trail.

The sheath which turns the elevating screw is revolved by a worm wheel carried in bearings on the socket. The outer end of the worm spindle carries a spur wheel which gears into teeth cut inside the back of the elevating wheel; the latter rides on the continuation of one of the trunnions of the traversing bed. A small link on the same trunnion supports the outer end of the worm spindle and keeps the gears correctly in mesh.

The elevating screws have three threads to an inch; the worm wheel has 30 teeth, and the worm is triple-threaded. The gear between elevating wheel and pinion is 5 to 1. The effect is to raise the breech one third of an inch for every turn of the hand-wheel, so that 36 turns are required to move the gun from maximum elevation to the horizontal position. This is rather a slow gear, but, with a 10-inch elevating wheel, should be a smooth and powerful one. It allows a 28-lb. preponderance, which prevents any possibility of play in the elevating screws.

The Traversing Bed.

This is a steel block carried on trunnions on the head of the elevating screw socket. The block is rigidly stayed to the axle (which moves with it, as will be remembered) by the bracket stay shown in Fig. 1 on the right side, and by a tubular stay to the shoulder of the axle-tree on the left. The traversing platform supports the traversing plate at the rear end of the cradle. The traversing worm, spindle, and hand-wheel are carried on the cradle and traverse with it.

The Range Drum.

This is carried on the bracket stay on the right of the gun, and faces so that it can be read by the No. 1 from the end of the trail.

The drum is of ideal simplicity, consisting of only two pieces, besides the shifting fuze-scale. It is worked by a toothed arc (which is really a portion of a large bevelled wheel) carried by the radius bar, which arc engages with a bevel wheel formed on the back of the drum.

It will be seen that this arrangement does away with any error which may arise from inaccuracy in the working of the laying or elevating gear. If the drum were connected by gearing to the elevating hand-wheel, any error due to play, wear, or backlash in the gear would be transmitted to the drum. As it is, the motion of the drum is governed by the relative motion of the bracket arm which carries it, which moves with the gun, and the radius bar, which carries the sighting telescope. Thus the drum always measures the true angle between the axis of the piece and the line of sight, quite independently of the action of the elevating and laying screws. In fact, so far as the drum is concerned, its action would not be effected if the elevating were done with handspikes and quoin.

THE SIGHT.

The sighting telescope is fixed as high as is possible consistently with rigidity. The object of a high line of sight is to be able to fire from behind a crest without undue exposure. Thus, in the design the telescope is 4 ft. above the ground; this enables the gun to be run back till only 8 inches of the top of the shield shows over the crest, while the layer is still able to see the target.

For indirect laying, the telescope must be capable of being directed at an aiming point to a flank or to the rear. For this purpose it is made to draw out of its socket till it is above the level of the wheels. A graduated base-plate measures the angle between aiming point and target. This base-plate is exactly similar to that on the battery director, except that it has in addition a tangent screw reading to five minutes for giving deflection.

The telescope is so placed that it passes through the shield near its vertical axis. This allows the hole in the shield to be but little larger than the telescope. A slit in the shield, covered by a flap door, allows the telescope to be raised to the high position.

The telescope itself is an erecting telescope magnifying about five diameters; it has a field of 6° with a horizontal pointer. It is about one foot long, with an object-glass 1¼ inches in diameter. No open sights are provided except a foresight and backsight on the telescope for quick laying at close quarters..

For travelling, the telescope with its stem is drawn out of the socket and carried in a padded case at the back of the shield.

The clinometer is of the arc pattern, attached to the telescope socket; it is set low down for convenience of reading.

DEFECTS OF PROPOSED SIGHT.

The sighting arrangement described above, which is copied in principle from the French sight, is efficient up to a certain point. It has, however, two essential drawbacks.

AA

In the first place it does not automatically correct for drift. In equipments with an intermediate carriage it is possible to incline the trunnions of the cradle to an angle equal to the main angle of drift; but in this design the horizontal pivot is the axletree itself, and this method is not applicable. With the independent line of sight there is of course no tangent scale to set at an angle. Compensating gear to correct for drift might be added, but the result would hardly be worth the complication. Accordingly, the correction for drift must be read off on the deflection corrector described below, and given by the layer on the base-plate of the telescope.

In the next place, the proposed sight is not a "reciprocating" one. The telescope is not supported on the cradle, which is parallel to the gun, but upon the radius bar, which is not. No amount of inclining the vertical support of the telescope would compensate for one wheel being higher than the other.

At ordinary targets it will not be necessary to correct for difference of level of wheels. But when firing at a shielded gun accuracy of direction is essential. Accordingly a "deflection corrector" is fixed to the back of the shield in front of the layer. This device is shown in principle in the diagram, Fig. 14. It consists of a pivoted level

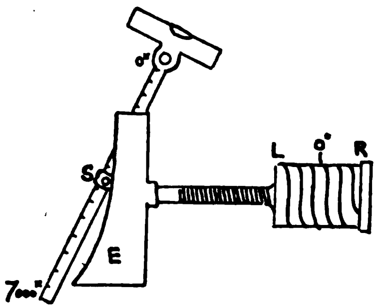


FIG. 14.
DEFLECTION CORRECTOR.

with a long stem, graduated in yards of range or (more correctly) in degrees of quadrant elevation. A stud *S* can be shifted up and down the graduated stem, and is pressed by a spring against the edge of the plate *E*, which is traversed by a drum spirally graduated in degrees and minutes of deflection. It will be seen from the figure that the greater the elevation the more turns have to be given to the drum to bring the bubble to the centre.

The edge of the plate *E* is not straight, but is curved to the curve of drift, so that the reading on the drum gives the combined deflection due to drift and difference of level of wheels.

So far as the writer is aware, this instrument is a novelty. There is however nothing new in the mechanism, which is imitated from the Watkin rangefinder.

It will be seen that by abandoning the old tangent scale or arc scale in favour of the range dial and independent line of sight we sacrifice the possibility of automatically correcting for difference of level of wheels by levelling the back-sight.* For Field Artillery, however, this drawback is far outweighed by the advantage of relieving the layer of all concern about the elevation.

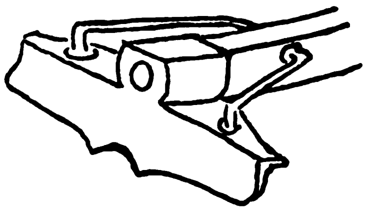


FIG. 16.
SPADE.

THE SPADE.

This is similar to the spade on the 15-pr. Q.F. (Ehrhardt) gun, which has been found to act remarkably well. It has, however, two points instead of one (*see* sketch, Fig. 16) which reduces the amount of downward projection. The spade is set 18° from the vertical; this angle has been found suitable for a 9-feet trail.

THE BRAKE GEAR.

This is of the pattern hitherto used in almost all modern guns. It is a combined firing and travelling brage, consisting of two brake blocks attached to arms pivoted to the trail. Tension rods attached to the blocks are fixed to a crossbar pivoted to the trail in front of the axletree. The effect of this is, that if either tension rod is shortened by a screw, both brake blocks are applied to the tires. The brake can be actuated from the front or from the rear of the shield, and has a quick release action (not shown) which enables it to be thrown off without unscrewing it.

It should be noted, however, that in some of the latest field guns there is a tendency to discard the firing brake as useless. Thus the American gun has a simple travelling brake, of the pattern now known as South African, applied to the wheels under the muzzle.

THE SHIELD.

Most Continental nations are adopting a shield either from 3 or 5 millimetres thick, calculated to keep out shrapnel bullets altogether and to stop infantry bullets at 200 to 300 yards. The Americans have adopted a 5-millimetre shield, which is practically bullet proof at all ranges. We may safely take a medium figure, 3½ millimetres or 0.14 inch. This thickness weighs about 6 lbs. to the square foot, so that the shield in the design, which is 22.5 square feet in area, will weigh 135 lbs. net without supports and attachments. Foreign makers usually leave the shield without any rim or edging. But in deference to English ideas of solidity we may add a small angle-steel rim at the sides only, leaving the top a plain edge.

Shields are made of nickel-chrome or nickel-tungsten steel. Thus the Ehrhardt shield and the American shield are made of steel with a tensile strength of 105 tons to the square inch.

* NOTE.—It is possible to use a reciprocating sight with the independent line of sight by employing either Col. Scott's automatic sight or Krupp's sight as fitted to the Italian gun.—H.A.B., 1910.

The upper part of the shield is hinged to the axletree and is supported by tubular stays bolted to the trail, as in Fig. 11. A disc of compressed felt is placed on either side of the shield at the point of attachment of the stay; this reduces vibration in travelling.

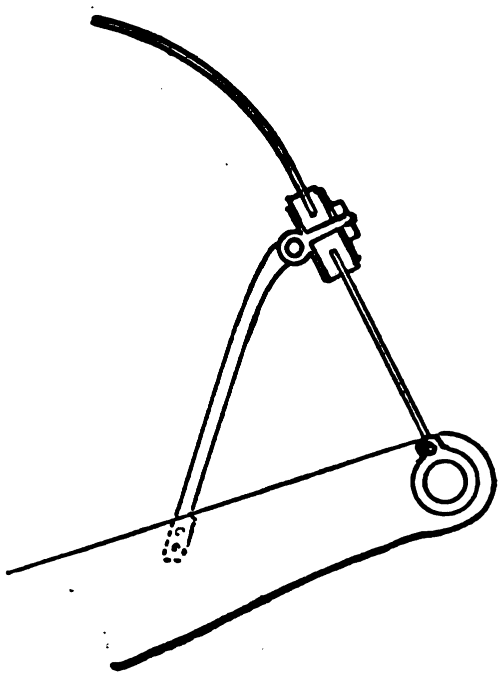


FIG. 17.

SHIELD SUPPORT.

The lower part of the shield is hung from the rear side of the axletree by short lengths of chain, which prevents it from being bent up if the wheels sink into the ground. It is secured by a clip to the under side of the axletree for travelling.

The front of the shield is covered with sheep-skin, with the wool on, dyed the same colour as the service uniform. This obviates the tendency of the shield to act as a heliograph when the sun strikes it. The Boers at Spion Kop covered the shields of their pom-poms with sacks to render them inconspicuous. (Von Wichmann.)

It will be noted that the shield in this design is curved well back. This is because the enemy's bullets do not come in horizontaily, but at angles of descent of 10 to 15° at medium ranges. The further back we get the shield the better the detachment will be protected. It is not desirable to have the shield higher than the wheels; but if more protection were required, a folding flap at the top of the shield might be added.

THE TRAIL EYE.

The French makers have adopted a spring trail eye, designed to ease the draught and reduce the travelling strains on the gun carriage. The same feature is found in the Krupp, St. Chamond, and Creusôt equipments. No details of the French device are available,

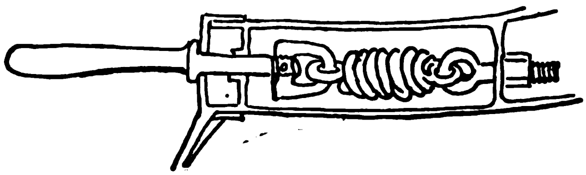


FIG. 13.
SKETCH OF SPRING TRAIL EYE.

but the arrangement sketched in Fig. 13 will probably answer the purpose. This pattern of spring is used for lorries and heavy drays.

SEATS FOR DETACHMENT.

Since a Q.F. field gun, capable of firing 20 rounds per minute, is always accompanied into action by its ammunition wagon, it is no longer necessary to carry the whole of the gun detachment on the gun and limber. Three men on the gun limber, three on the wagon limber, and No. 1 on his horse, make a full detachment. The place of a Q.F. wagon in action is beside its gun, so that no men are required to carry ammunition up to the gun. This innovation enables us to make the gun heavier and more powerful without increasing the weight on the gun wheels. We save 80 lbs. on the two axletree seats and foot rests, and some 3 cwt. on the two gunners—say $3\frac{1}{4}$ cwt. in all. We are thus able to provide a shield weighing 150 lbs., and to make the gun $2\frac{1}{4}$ cwt. heavier than the old B.L. equipment, without increasing the weight behind the team. The weight of the extra man on the limber will have to be allowed for by making the limber lighter and carrying fewer rounds.

ROUNDS ON THE GUN CARRIAGE.

In the new American equipment each gun carries four rounds, weighing with the tubes for carrying them about 80 lbs. This feature has not been embodied in the present design, for the following reason:

It is usually possible to bring a gun into action unseen by the enemy. But as soon as it opens fire the broad white flash of the smokeless powder catches the enemy's attention and draws his fire. If the gun opens fire before the wagon comes up, the wagon will have to drive up under fire. It is therefore generally desirable to wait (if necessary) for the wagon before opening fire. This being so, the extra four rounds on the gun would only be useful under exceptional circumstances.

MINOR DETAILS OF CARRIAGE.

In the drawings of the buffer, a long screw will be noticed at the rear end. This is Krupp's device for putting the initial compression

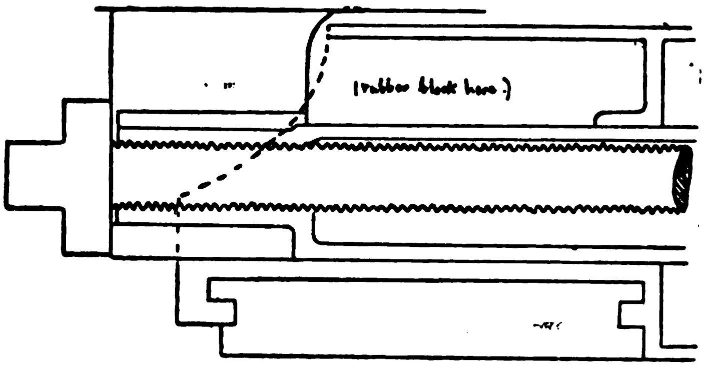


FIG. 6.

REAR END OF BUFFER AND COMPRESSOR SCREW.

on the running-up springs. The method of mounting the buffer and springs is as follows:—

Remove front plate of cradle; introduce the buffer with springs and parting plates, and press back by hand till the rear end of the buffer engages with compressor screw; wind up the screw by means of a handle till the buffer is home in the horn projecting downwards from the breech of the gun. The buffer is kept from turning by a wrench until it enters the horn, when a feather keeps it in the correct position. Finally, screw the front plate on to the piston rod and bolt it in its place.

TO FILL UP THE BUFFER.

The published drawings of the Krupp buffer do not show any filling plug. Krupp prefers to unscrew the whole stuffing-box without disturbing the packing. The following method (untried, and therefore open to suspicion) has been adopted in our present design. (See Fig. 3.)

In the front solid end of the hollow piston rod are bored two channels, one for the entrance of the oil or glycerine and the other for the escape of air. Both these channels are closed by one screw plug. In the normal position the inner ends of the channels are not within the buffer, but under the ring at the bottom of the gland. To fill up the buffer, slack the compressor screw three turns; this will allow the buffer to move forward up against the front plate of the cradle, and will bring the holes inside the buffer. Elevate the gun, take out the plug, and pour in the buffer liquid through the lower channel, while the air escapes through the upper channel; replace plug, and tighten the compressor screw.

AMMUNITION.

A detailed description of the ammunition involves the consideration of a problem almost as serious as that of the design of the gun. Briefly, the gun is to fire fixed ammunition ; the cordite charged is to be 20 oz. of cordite, Mark I., or a corresponding amount of cordite, tubular. Weight of fuzed shell, 15 lbs., to contain 310 bullets of 39 to the lb. and a driving charge of 2½ oz. black powder, besides 2 oz. of coarse black powder among the bullets as a smoke-producer. The body of the shell is not intended to break up on explosion. This corresponds in effect to the latest Ehrhardt construction.

A percentage of high-explosive shell are to be carried; these are to be of the Krupp pattern, loaded with gun-cotton powder.

The fuze to be a double-banked Bazichelli fuze as used by Krupp and Ehrhardt, available as a time fuze up to 7,000 yards.

WEIGHTS.

We can now proceed to sum up the weights of the different parts.

The gun, as has been said, weighs 782 lbs.; buffer casing and gland 79 lbs.; piston 16 lbs. and liquid 6¾ lbs.; springs and parting plates (by comparison with Ehrhardt) 70 lbs. The cradle weighs by measurement 157.5 lbs., taking nickel-steel at approximately 500 lbs. per cubic foot. The trail, of ¼" steel, weighs with traversing lever, spade, and all adjuncts 255 lbs.; this makes the lift at the trail handles 170 lbs. The elevating and laying gear, with radius bar, weigh 80 lbs.; traversing bed and stays, 30 lbs.; telescope, clinometer and supports 10 lbs.; brake gear, 80 lbs.; shield and stays, 150 lbs. The wheels weigh about 200 lbs. each, if made of Woolwich pattern, through the American 4′ 8″ wheel is considerably lighter. The axletree with its bronze sleeve weighs 120 lbs.

Add 50 lbs. for bolts, nuts and details, such as the telescope case and the sheepskin, and we get a grand total of 2265 lbs., or 20¼ cwt.

Some of the minor parts in this design have been made rather massive as compared with German practice; but even allowing for a reduction of a few pounds on the elevating gear and wheels, we shall barely get the weight of gun in action down to one ton, which is about one cwt. heavier than the average German 14½-pr, with M.V. of 1640 fs.

If a further reduction is desired it will have to be effected by reducing the diameter of the wheels, which not only reduces the weight of the wheels, but also the length and weight of the trail. Roughly speaking, one centimetre off the wheel means 5 kilos off the carriage, or one inch 27.5 lbs. At this rate, if we reduced the wheel from 4′ 8″ to 4′ 3″, the weight of the gun in action would be 1½ cwt. less or say 18¾ cwt. But whether the big wheel is not worth the extra 1½ cwt. is another question. It must be remembered, moreover, that if we cut down the wheel we also (according to the above estimate) cut down the height of the shield, and to obtain equal protection we should have to add five inches to the top of the shield.

The writer is not vain enough to suppose that the design here worked out is the best possible construction for a field-gun. It is put forward principally as an academic design, intended to give officers an idea of the results which may be expected from a safe combination of proved and tested elements.

Aldershot, 1904. H. A. B.

TABLES

FOR USE IN

GUNNERY.

TABLE OF WEIGHT AND STRENGTH OF MATERIALS.

Material	Specific Gravity.	Weight of 1 cubic foot. lbs.	Weight of 1 cubic inch. lbs.	Strength per square inch.	
				Tensile tons.	Crushg. tons.
Aluminium, cast	2.56	160	0.092	—	—
Brass (3 copper to 1 zinc) ..	8.397	524	0.3	13.1	—
Aluminium bronze (copper 90, aluminium 10)	7.68	478	0.276	33	—
Aluminium zinc alloy (Al. 85.5, zinc 13.75, copper 0.5 magnesium 0.25)	3.18	198	0.115	17	—
Elswick bronze	8.2	510	0.296	28	—
Manganese bronze (75 copper, 5 tin, 20 manganese)	8.56	535	0.31	28	—
Phosphor bronze .. .. (89 copper, 10 tin, 1 phosphorus)	8.5	530	0.307	21	—
Silicon bronze (88 copper, 10 tin, 2 silicon)	8.9	555	0.32	35	25
Copper, sheet	8.78	548	0.316	13.4	—
Copper, wire	8.9	555	0.32	26	—
Gun metal (10 copper, 1 tin) ..	8.464	528	0.306	16.1	—
Iron, wrought, from	7.5	475	0.273	16	16
to	7.8	487	0.281	29	18
average ..	7.78	485	0.28	22	17
Iron, cast, from	7	437	0.252	6	36
to	7.6	474	0.273	13	64
from	7.23	451	0.26	7.3	48
Lead, cast	11.36	709	0.408	3.1	—
Mercury	13.596	849	0.491	—	—
Mixed metal .. .. (4 lead to 1 antimony) ..	9	562	0.324	—	—
Ditto (9 lead to 1 antimony) ..	10	624	0.36	—	—
Steel, mild, 6% nickel ..				30	35
Steel, gun, 6% nickel (1) ..				49.4	50
Steel, nickel, hard for shields (2)	8	497	0.287	106.6	150
Ditto, for axletrees (3) ..				50.419	60
Steel wire or ribbon				120	—
Tungsten or wolfram	18.6	1161	0.6716	—	—
Zinc, cast	7	437	0.252	3.3	—

(1) Elastic limit 32 tons, final extension 18.6%
(2) „ 80 „ „ „ 5.5%
(3) „ 47.7 „ „ „ 23%
(Ehrhardt).

WEIGHT AND STRENGTH OF TIMBER,

Material.	Specific Gravity.	Weight of 1 cubic foot. lbs.	Weight of 1 cubic inch. lbs.	Strength per square inch.	
				Tensile lbs.	Crushg. lbs.
Oak	0.93	57	0.0332	15000	8250
Ash	0.75	46.5	0.027	17700	9000
Elm	0.55	35	0.02	14000	10300
Fir	0.53	33.5	0.19	11000	5500

TABLE OF SHRAPNEL BULLETS.

(85 lead to 15 antimony. Sp. Gr. 9.5.)

Weight to the pound.	Weight grammes approximate.	Nation.	Diameter, inches	Ballistic Coefficient $\frac{w}{d^2}$	Lowest effective velocity for 60 foot-lbs. f.s.
29	15.7	Krupp Howitzers ..	.5774	.1034	335
28.4	16	" "	—	—	—
29.3	15.5	—	—	—	—
30.2	15	—	—	—	—
32.5	14	—	—	—	—
35	13	England (Howitzers) America ..	.5415	.09740	368.6
36.4	12.5	Switzerland ..	.5341	.09608	376.4
38	12	France	.5268	.09477	384.1
39.5	11.5	—	—	—	—
41	11.1	—	—	—	—
41.3	11	Denmark, Holland, &c.	.5136	.09241	398.9
42	10.8	England ..	.5096	.09169	403.8
43	10.6	Russia	.5056	.09095	408.6
43.5	10.5	—	.5038	.09064	410.9
45	10	Germany, Spain, &c.	.4980	.08960	418.0
50	9.1	—	—	—	—
50.5	9	Austria, Italy, &c. ..	.4807	.08586	439.5

Remarks.

Shrapnel bullets are almost invariably made of an alloy of lead and antimony, varying from 9 lead and 1 antimony to 4 lead and 1 antimony, which is the proportion given in the Treatise on Ammunition. The former composition is rather too soft, as the bullets tend to get flattened and to lose their shape on the shock of discharge; the latter is undesirably light. A good medium composition, used by most Continental nations, is 85 lead to 15 antimony. The best bullets are made by feeding a rod of metal into a machine which compresses it into bullets; these are about 1 per cent. denser than cast bullets, and their ballistic co-efficient 3 per cent. higher. The figures in the above table refer to cast bullets, but most foreign firms now use pressed bullets.

For ordinary work it will be found sufficient to take the first two significant figures of the ballistic co-efficients given above. For cast bullets, a value of *Kappa* of 1.04 should be used. In using the 1909 Tables, the above values of $\frac{w}{d^2}$ should be divided by a modifying factor of 1.75, which includes this value of Kappa.

If one bullet weighs x grammes, then there are $\frac{1000}{x}$ to the kilo or $\frac{1000}{x \times 2.2}$ to the pound.

MILLIMETRES AND THEIR EQUIVALENTS IN INCHES.

Mm.	Inches.	Mm.	Inches.	Mm.	Inches.	Mm.	Inches.	Mm.	Inches.
1	·0394	21	·8268	41	1·6142	61	2·4016	81	3·1891
2	·0787	22	·8661	42	1·6536	62	2·4410	82	3·2284
3	·1181	23	.9055	43	1·6929	63	2·4803	83	3·2678
4	·1575	24	·9449	44	1·7323	64	2·5197	84	3·3072
5	·1968	25	·9843	45	1·7717	65	2·5591	85	3·3466
6	·2362	26	1·0236	46	1·8110	66	2·5984	86	3·3859
7	·2756	27	1·0630	47	1·8504	67	2·6378	87	3·4253
8	·3150	28	1·1024	48	1·8898	68	2·6772	88	3·4647
9	·3543	29	1·1417	49	1·9292	69	2·7165	89	3·5040
10	·3937	30	1·1811	50	1·9685	70	2·7560	90	3·5434
11	·4331	31	1·2205	51	2·0079	71	2·7954	91	3·5828
12	·4724	32	1·2598	52	2·0472	72	2·8347	92	3·6221
13	·5118	33	1·2992	53	2·0866	73	2·8741	93	3·6615
14	·5512	34	1·3386	54	2·1260	74	2·9135	94	3·7009
15	·5906	35	1·3780	55	2·1654	75	2·9529	95	3·7403
16	·6299	36	1·4173	56	2·2047	76	2·9922	96	3·7796
17	·6693	37	1·4567	57	2·2441	77	3·0316	97	3·8190
18	·7087	38	1·4961	58	2·2835	78	3·0710	98	3·8584
19	·7480	39	1·5354	59	2·3228	79	3·1103	99	3·8977
20	·7874	40	1·5748	60	2·3622	80	3·1497	100	3·9370

TO CONVERT METRIC UNITS TO BRITISH, AND VICE VERSÂ.

Kilo-metres		Eng. miles	Square Kilo-metres		Sq. Eng. miles	Metres		Yards	Kilogrs		lbs. Avoir	Litres		Gal-lons.
1·609	1	0·621	2·592	1	0·386	0·914	1	1·094	0·454	1	2·20	4·54	1	0·22
3·219	2	1·243	5·184	2	0·772	1·829	2	2·187	0·907	2	4·41	9·09	2	0·44
4·828	3	1·863	7·776	3	1·158	2·743	3	3·281	1·361	3	6·61	13·63	3	0·66
6·438	4	2·486	10·368	4	1·544	3·658	4	4·374	1·814	4	8·82	18·17	4	0·88
8·047	5	3·107	12·960	5	1·930	4·572	5	5·468	2·268	5	11·02	22·72	5	1·10
9·656	6	3·728	15·552	6	2 316	5·486	6	6·562	2·722	6	13·23	27·26	6	1·32
11·265	7	4·350	18·144	7	2·702	6·401	7	7·655	3·175	7	15·43	31·80	7	1·54
12·875	8	4·971	20·736	8	3·088	7·315	8	8·749	3·629	8	17·64	36·35	8	1·76
14·484	9	5·592	23·328	9	3·474	8·229	9	9·843	4·082	9	19·84	40·89	9	1·98
16·093	10	6·214	25·920	10	3·860	9·144	10	10·936	4 536	10	22·05	45·43	10	2·20
32·186	20	12·428	51·840	20	7·720	18·288	20	21·873	9·072	20	44·09	90·87	20	4·40
48·279	30	18·641	77·760	30	11·580	27·432	30	32·809	13·608	30	66·14	136·30	30	6·60
64·373	40	24·855	103·680	40	15·440	36 576	40	43·745	18·144	40	88·18	181·74	40	8·80
80·496	50	31·069	129·600	50	19·300	45·719	50	54·682	22·679	50	110·23	227·17	50	11·00
96·559	60	37·283	155·520	60	23·160	54·863	60	65·618	27·215	60	132·28	272·61	60	13·20
112·652	70	43·497	181·440	70	27·020	64·007	70	76·554	31 752	70	154·32	318·04	70	15·40
128·746	80	49·710	207·360	80	30·880	73·151	80	87·491	36·288	80	176·37	363·48	80	17·60
144·838	90	55·924	233·380	90	34·740	82·295	90	98·427	40·823	90	198·42	408·91	90	19·80
160·932	100	62·138	259 200	100	38·601	91·438	100	109·363	45·359	100	220·46	454·35	100	22·01

Example.—10 miles = 16.093 kilometres, or 10 kilometres = 6.214 miles.
Similarly, 6 lbs. = 2.722 kilogrammes, or 6 kilogrammes = 13.23 lbs.
1 square decimetre = 15.5 square inches. 1 cubic decimetre = 1 litre = 61 cubic inches.
100 grammes = 3.52 oz.

CONVERSION OF MEASURES.

(Chiefly based on data contained in Col. Noble's Useful Tables.)

LENGTH.

Metric to English.

Metres	Yards.	Feet.	Inches.
1	1.0936	3.2809	39.37
2	2.1873	6.5618	78.74
3	3.2809	9.8427	118.11
4	4.3745	13.1236	157.48
5	5.4682	16.4045	196.85
6	6.5618	19.6854	236.22
7	7.6554	22.9663	275.60
8	8.7491	26.2472	314.97
9	9.8427	29.5281	354.34

English to Metric.

Yards	Metres.	Feet.	Metres.	Ins.	Centimetres.
1	0.91438	1	0.30479	1	2.5400
2	1.82877	2	0.60959	2	5.0729
3	2.74315	3	0.91438	3	7.6199
4	3.65753	4	1.21918	4	10.1598
5	4.57192	5	1.52397	5	12.6998
6	5.48630	6	1.82877	6	15.2397
7	6.40068	7	2.13356	7	17.7797
8	7.31507	8	2.43836	8	20.3196
9	8.22945	9	2.74315	9	22.8596

Metric Table of Length.

Millimetres.

10 = 1 centimetre
100 = 1 decimetre
1000 = 1 metre

Metres.

10 = 1 decametre
100 = 1 hectometre
1000 = 1 kilometre

WEIGHT.

Kilogram's	Tons.	Pounds Avoir-dupois.	Grains Troy.
1	.000984	2.2046	15432.3
2	.001968	4.4092	30864.7
3	.002953	6.6139	46297.0
4	.003937	8.8185	61729.4
5	.004921	11.0231	77161.7
6	.005905	13.2277	92594.1
7	.006889	15.4323	108026.4
8	.007874	17.6370	123458.8
9	.008858	19.8416	138891.1

Tons.	Metric tons or milliers.	Pounds Avoir-dupois.	Kilo-grammes	Grains Troy.	Grammes.
1	1.016	1	0.4536	1	.0648
2	2.032	2	0.9072	2	.1296
3	3.048	3	1.3608	3	.1944
4	4.064	4	1.8144	4	.2592
5	5.080	5	2.2680	5	.3240
6	6.096	6	2.7216	6	.3888
7	7.112	7	3.1751	7	.4536
8	8.128	8	3.6287	8	.5184
9	9.144	9	4.0823	9	.5832

1000 Grammes = 1 kilogramme. 1000 Kilogrammes = 1 metric ton.

One kilogramme is the weight of one litre, that is, one cubic decimetre, of water. One cubic foot of water weighs 1000 ounces. One pound avoirdupois = 7000 grains troy = 453.6 grammes.

PRESSURE.

Metric and Atmospheric to English.

Kilogrammes per sq. cm.	Pounds per sq. inch.	Tons per sq. inch.	Atmospheres.	Lbs. per sq. inch.	Tons per sq. inch.
1	14.223	.00635	1	14.7	.00656
2	28.446	.01270	2	29.4	.01313
3	42.668	.01905	3	44.1	.01969
4	56.891	.02540	4	58.8	.02625
5	71.114	.03175	5	73.5	.03281
6	85.337	.03810	6	88.2	.03938
7	99.560	.04445	7	102.9	.04594
8	113.780	.05080	8	117.6	.05250
9	128.005	.05715	9	132.3	.05906

English to Metric and Atmospheric.

Pounds per sq. inch.	Kilogrammes per sq. cm.	Atmospheres.	Tons per sq. inch.	Kilogrammes per sq. cm.	Atmospheres.
1	.07031	.068	1	157.49	152.38
2	.14062	.136	2	314.99	304.76
3	.21093	.204	3	472.48	457.14
4	.28124	.272	4	629.97	609.52
5	.35155	.340	5	787.47	761.91
6	.42186	.408	6	944.96	914.29
7	.49217	.476	7	1102.45	1066.67
8	.56248	.544	8	1259.95	1219.05
9	.63279	.612	9	1417.44	1371.43

ENERGY.

Metric to English.

Metre-tons.	Foot-tons.
1	3.2291
2	6.4581
3	9.6872
4	12.9162
5	16.1453
6	19.3743
7	22.6034
8	25.8324
9	29.0615

English to Metric.

Foot-tons.	Metre-tons.
1	0.3097
2	0.6194
3	0.9291
4	1.2388
5	1.5484
6	1.8581
7	2.1678
8	2.4775
9	2.7872

N°	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	4	8	12	17	21	25	29	33	37
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4	8	11	15	19	23	26	30	34
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3	7	10	14	17	21	24	28	31
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16	19	23	26	29
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15	18	21	24	27
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3	6	8	11	14	17	20	22	25
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3	5	8	11	13	16	18	21	24
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	2	5	7	10	12	15	17	20	22
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2	5	7	9	12	14	16	19	21
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2	4	7	9	11	13	16	18	20
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11	13	15	17	19
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	12	14	16	18
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10	12	14	15	17
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9	11	13	15	17
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	11	12	14	16
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9	10	12	14	15
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	10	11	13	15
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	9	11	13	14
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	8	9	11	12	14
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	9	10	12	13
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	9	10	11	13
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	8	10	11	12
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	8	9	11	12
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6	8	9	10	12
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	8	9	10	11
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6	7	9	10	11
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6	7	8	10	11
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6	7	8	9	10
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	7	8	9	10
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	6	7	8	9	10
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5	6	7	9	10
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5	6	7	8	9
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	6	7	8	9
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5	6	7	8	9
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5	6	7	8	9
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1	2	3	4	5	6	7	8	9
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5	6	7	7	8
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5	5	6	7	8
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	4	5	6	7	8
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	4	5	6	7	8
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	3	4	5	6	7	8
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	3	4	5	6	7	8
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	2	3	4	5	6	7	7
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	2	3	4	5	6	6	7
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	2	3	4	5	6	6	7

N°	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1	2	2	3	4	5	5	6	7
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1	2	2	3	4	5	5	6	7
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1	2	2	3	4	5	5	6	7
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1	1	2	3	4	4	5	6	7
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1	1	2	3	4	4	5	6	7
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1	1	2	3	4	4	5	6	6
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1	1	2	3	4	4	5	6	6
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1	1	2	3	3	4	5	6	6
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1	1	2	3	3	4	5	5	6
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1	1	2	3	3	4	5	5	6
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1	1	2	3	3	4	5	5	6
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1	1	2	3	3	4	5	5	6
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1	1	2	3	3	4	5	5	6
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1	1	2	3	3	4	4	5	6
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1	1	2	3	3	4	4	5	6
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1	1	2	2	3	4	4	5	6
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1	1	2	2	3	4	4	5	5
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1	1	2	2	3	4	4	5	5
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1	1	2	2	3	4	4	5	5
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1	1	2	2	3	4	4	5	5
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1	1	2	2	3	3	4	5	5
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1	1	2	2	3	3	4	5	5
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1	1	2	2	3	3	4	4	5
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1	1	2	2	3	3	4	4	5
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1	1	2	2	3	3	4	4	5
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1	1	2	2	3	3	4	4	5
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1	1	2	2	3	3	4	4	5
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1	1	2	2	3	3	4	4	5
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1	1	2	2	3	3	4	4	5
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1	1	2	2	3	3	4	4	5
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1	1	2	2	3	3	4	4	5
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1	1	2	2	3	3	4	4	5
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0	1	1	2	2	3	3	4	4
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0	1	1	2	2	3	3	4	4
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0	1	1	2	2	3	3	4	4
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0	1	1	2	2	3	3	4	4
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0	1	1	2	2	3	3	4	4
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0	1	1	2	2	3	3	4	4
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0	1	1	2	2	3	3	4	4
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0	1	1	2	2	3	3	4	4
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0	1	1	2	2	3	3	4	4
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0	1	1	2	2	3	3	4	4
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0	1	1	2	2	3	3	4	4
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0	1	1	2	2	3	3	4	4
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0	1	1	2	2	3	3	4	4

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